CELLULAR

Positioning Implementation

Positioning Implementation and Aiding Features in u-blox cellular modules

Application Note

Abstract

This document describes the implementation of the GNSS interface and aiding clients in u-blox cellular modules. Techniques for Hybrid Positioning and CellLocate® are also described.

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This document applies to the following products:

Name
LEON-G1 series
LEON-G2 series
LISA-U1 series
LISA-U2 series
LISA-C2 series
SARA-G340 series
SARA-G350 series
SARA-U2 series

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Preface

u-blox Technical Documentation

As part of our commitment to customer support, u-blox maintains an extensive volume of technical documentation for our products. In addition to our product-specific technical data sheets, the following manuals are available to assist u-blox customers in product design and development.

- **AT Commands Manual**: This document provides the description of the AT commands supported by u-blox cellular modules.
- **System Integration Manual**: This document describes u-blox cellular modules from the hardware and the software point of view. It provides hardware design guidelines for the optimal integration of the cellular module in the application device and it provides information on how to set up production and final product tests on application devices integrating the cellular module.
- **Application Notes**: These documents provide guidelines and information on specific hardware and/or software topics on u-blox cellular modules. See Related documents for a list of application notes related to your cellular module.

How to use this Application Note

This application note describes how to use the GNSS interface and control functionalities and aiding clients in u-blox cellular modules.

The following symbols highlight important information within the application note:

☞ An index finger points out key information pertaining to module integration and performance.

⚠ **A warning symbol indicates actions that could negatively influence or damage the module.**

Questions

If you have any questions about u-blox cellular modules, please:

- Read this application note and the available technical documentation carefully.
- Contact our information service on the homepage http://www.u-blox.com.

Technical Support

Worldwide Web

Our website (www.u-blox.com) is a rich pool of information. Product information and technical documents can be accessed 24h a day.

By E-mail

If you have technical problems or cannot find the required information in the provided documents, contact the closest Technical Support office. To ensure that we process your request as soon as possible, use our service pool email addresses rather than personal staff email addresses. Contact details are at the end of the document.

Helpful Information when Contacting Technical Support

When contacting Technical Support please have the following information ready:

- Module type (e.g. LISA-U200) and firmware version
- Module configuration
- Clear description of your question or the problem
- A short description of the application
- Your complete contact details

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1 Introduction

1.1 Scope

This document describes how to use the GNSS interface and control functionalities and aiding clients in u-blox cellular modules. In this document, "GPS", "GNSS" and "GPS/GNSS" refer generally to any GNSS (Global Navigation Satellite System), not to a specific one (such as GPS or GLONASS).

The following sections describe:

- Hardware and software architecture implemented in the cellular module for connecting u-blox positioning chips and modules to u-blox cellular modules
- Implementation of aiding clients. Aiding clients are software tools in the cellular modules, providing improvement of GNSS performance
- Hybrid positioning and CellLocate® features. These features provide location information when the GNSS signal is weak or absent

☞ The GNSS interface is not supported by LISA-U200-00S version or by LISA-C200-x2S and previous versions.

1.2 AT commands

Table 1 lists the AT commands described in this document:

AT command	Description
+UGPS	GNSS power management configuration
+UGIND	Assisted GNSS unsolicited indication
+UGPRF	GNSS Profile configuration
+UGAOP	AssistNow Online configuration
+UGAOF	AssistNow Offline configuration
+UGSRV	Aiding server configuration
+UGAOS	GNSS aiding request command
+ULOC	Ask for localization information
+ULOCGNSS	Configure GNSS sensor
+ULOCCELL	Configure cellular location sensor (CellLocate®)

Table 1: GNSS AT commands

For a complete description of the AT commands syntax, see u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20].

1.3 GNSS aiding features compatibility matrix

For a simpler integration of u-blox cellular modules and positioning products, u-blox cellular modules feature u-blox A-GNSS services (AssistNow Online, AssistNow Offline) for faster and more accurate GNSS performance.

Support of the different types of embedded GNSS aiding features can vary depending on the u-blox cellular module series and version. See Table 2 for a complete overview of the aiding modes supported by u-blox cellular modules.

u-blox cellular module	Local Aiding	AssistNow Online	AssistNow Offline	AssistNow Autonomous
LEON-G100 / LEON-G200 series (except LEON-Gx00-05S and previous versions)	YES	YES	YES	YES
LEON-G100-05S / LEON-G200-05S and previous versions	YES	YES	YES	NO
LISA-U1 series	YES	YES	YES	YES
LISA-U2 series (except LISA-U200-00S)	YES	YES	YES	YES
LISA-U200-00S	NO	NO	NO	NO
LISA-C2 series (except LISA-C200-x2S and previous versions)	YES	YES	YES	YES
LISA-C200-x2S and previous versions	NO	NO	NO	NO
SARA-G340 / SARA-G350 series	YES	YES	YES	YES
SARA-U2 series	YES	YES	YES	YES

Table 2: GNSS aiding feature compatibility matrix

2 Hardware architecture

2.1 General considerations

Combining a u-blox cellular module with a u-blox positioning chip/module gives designers full access to the GNSS receiver directly via the cellular module, so that a second interface connected to the GNSS receiver is unnecessary. Control messages are relayed to the GNSS receiver via a dedicated I²C compliant DDC interface. AT commands sent through an AT interface allow full control of the GNSS receiver from the host processor.

☞ On LEON-G100 / LEON-G200, LISA-U1, LISA-C200 and SARA-G340 / SARA-G350 series modules, the DDC (I²C) interface is exclusively dedicated for connection to u-blox GNSS receivers and cannot be used to control other peripherals: only the AT+UGPS command enables the DDC interface (for more details see the u-blox AT Commands Manual [1]).

☞ The u-blox cellular module's DDC interface pins (i.e. the **SDA** and **SCL** pins) must be properly connected to the DDC interface pins of the u-blox GNSS receiver on the application board to take advantage of the embedded GNSS aiding features.

☞ Support of the different types of embedded GNSS aiding features can vary depending on the u-blox cellular module series and version. See Table 2.

For compliance with the I²C bus specifications, the module pads of the bus interface are open drain output, therefore pull-up resistors must be used. Since these pull-up resistors are not mounted on the cellular module, they must be externally provided and their values must conform to the I²C bus specifications [9]. The signal shape is defined by the pull-up resistors' values and bus capacitance. Long wires on the bus will increase the capacitance: if this capacitance value is highly increased, pull-up resistors with nominal resistance value lower than 4.7 kΩ should be used to match the I²C bus specifications [9] regarding rise and fall times of the signals.

☞ Pull-up resistors for the DDC lines must be connected to a proper supply voltage. The nominal value of the resistors may differ depending on the u-blox cellular module series.

☞ Capacitance and series resistance must be limited on the bus to match the I²C specifications [9] (the maximum allowed rise time on the **SCL** and **SDA** lines is 1.0 µs). Route connections must be kept as short as possible.

The u-blox cellular modules provide additional custom functions over GPIO pins to improve the integration with u-blox positioning chips and modules. GPIO pins can handle:

- GNSS receiver power-on/off: "GNSS supply enable" function
- The wake-up of the cellular module from low power idle-mode when the GNSS receiver is ready to send data: "GNSS data ready" function
- The RTC synchronization signal to the GNSS receiver: "GNSS RTC sharing" function

☞ Support of the different additional functionalities configured by the cellular module's GPIOs can vary depending on the u-blox cellular module series and version. See the following section 2.2.

The hardware connections of different u-blox cellular modules and u-blox GNSS receivers are described in detail in the sections 2.3, 2.4, 2.5, 2.6 and 2.7, while jamming and EMC considerations are illustrated in section 0. For further design-in information, see the corresponding cellular module System Integration Manual [4] [5] [18] [19], and the corresponding u-blox GNSS receiver Hardware Integration Manual.

2.2 GPIO functions compatibility matrix

On u-blox cellular modules, GPIO pins can be conveniently configured to provide GNSS custom functions via the +UGPIOC AT command. The custom functions available can vary depending on the u-blox cellular modules series and version: Table 3 provides an overview of the GNSS custom functions supported by u-blox cellular modules.

u-blox cellular module	GNSS supply enable	GNSS data ready	GNSS RTC sharing	Remarks
LEON-G100 / LEON-G200 series (except LEON-Gx00-05S and previous versions)	YES	YES	YES	
LEON-G100-05S / LEON-G200-05S and previous versions	YES	NO	NO	The modules do not enter low power idle-mode when the DDC (I^2C-bus) interface is enabled by the AT+UGPS command, even if power saving is enabled by the AT+UPSV command.
LISA-U1 series	YES	YES	YES	
LISA-U2 series (except LISA-U200-00S)	YES	YES	YES	
LISA-U200-00S	NO	NO	NO	
LISA-C2 series (except LISA-C200-x2S and previous versions)	YES	YES	NO	
LISA-C200-x2S and previous versions	NO	NO	NO	
SARA-G340 / SARA-G350 series	YES	YES	YES	
SARA-U2 series	YES	YES	YES	

Table 3: GPIO functions compatibility matrix

For a complete description of the +UGPIOC AT command syntax, see u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20].

2.2.1 "GNSS supply enable" function

The "GNSS supply enable" function improves the power consumption of the positioning chip/module. When GNSS functionality is not required, the cellular module controlled by the application processor can completely switch off the GNSS receiver using AT commands.

The **GPIO2** pin is by default configured to provide the "GNSS supply enable" function (parameter <gpio_mode> of AT+UGPIOC command set to 3 by default), to enable or disable the supply of the u-blox GNSS receiver connected to the cellular module by the AT+UGPS command. The pin is set as:

- Output / High, to switch on the u-blox GNSS receiver, if the parameter <mode> of AT+UGPS command is set to 1
- Output / Low, to switch off the u-blox GNSS receiver, if the parameter <mode> of AT+UGPS command is set to 0 (default setting)

The pin must be connected to the active-high enable pin (or the active-low shutdown pin) of the voltage regulator that supplies the u-blox positioning chip/module on the application board.

☞ On LEON-G, SARA-G340 / SARA G350, LISA-C2, LISA-U1 and SARA-U2 / LISA-U2 (prior to 03S product versions) series it is not possible to use the GNSS if **GPIO2** pin is not configured as "GNSS supply enable" function.

2.2.1 "GNSS data ready" function

See Table 28 to see which u-blox positioning products support the "GNSS data ready" function.

The "GNSS data ready" function informs the cellular module that the GNSS receiver is ready to send data on the DDC (I^2C) interface. If the cellular module is in low power idle-mode and the power-saving is enabled, it wakes up to receive the data sent by the GNSS receiver. The function optimizes the cellular module power consumption, since it wakes-up only when there is data ready from the GNSS receiver.

The **GPIO3** pin is configured by default to provide the "GNSS data ready" function (parameter <gpio_mode> of AT+UGPIOC command set to 4 by default). The pin senses when the u-blox GNSS receiver connected to the cellular module is ready to send data by the DDC (I^2C) interface. The pin is set as:

- Input, when the <mode> parameter of the +UGPS AT command is set to 1 and the parameter <GPS_IO_configuration> of the +UGPRF AT command is set to 16. This is used to detect the line status, and to wake up the cellular module from low power idle-mode when the u-blox GNSS receiver is ready to send data by the DDC (I^2C) interface. For more details on AT commands description see the u-blox AT commands manual [1]
- Tri-state with an internal active pull-down enabled (the default setting)

Connect the pin providing the "GNSS data ready" function to the data ready output of the u-blox positioning chip/module (i.e. TxD1) on the application board.

For more details see the section 3.2.

2.2.2 "GNSS RTC sharing" function

See Table 30 to see which u-blox positioning products support the "GNSS RTC sharing" function.

The "GNSS RTC sharing" function provides a synchronization timing signal from the GNSS receiver to the cellular module. At the power-up of the u-blox GNSS receiver, the cellular module passes the timing back to GNSS receiver.

The **GPIO4** pin is by default configured to provide the "GNSS RTC sharing" function (parameter <gpio_mode> of +UGPIOC AT command set to 5 by default), to provide an RTC (Real Time Clock) synchronization signal at the power-up of the u-blox positioning chip/module connected to the cellular module. The pin is set as:

- Output, to provide a synchronization timing signal to the u-blox GNSS receiver for RTC sharing if the parameter <mode> of AT+UGPS command is set to 1 and the parameter <GPS_IO_Configuration> of +UGPRF AT command is set to 32; for more details on AT commands description see the u-blox AT commands manual [1]
- Output / Low, otherwise (default setting)

Connect the pin providing the "GNSS RTC sharing" function to the synchronization timing input of the u-blox GNSS receiver (the **EXTINT0** pin of the u-blox GNSS receiver) on the application board.

For more details see the section 4.2.1.

2.3 Hardware architecture with LEON-G100 / LEON-G200 series

2.3.1 Application circuit for LEON-Gx00-05S and LEON-Gx00-04S versions

☞ The pull-ups must be connected to a supply voltage of 3.0 V (typical), since this is the voltage domain of the DDC (I^2C) pins of LEON-G100 / LEON-G200 series modules (for detailed electrical characteristics see LEON-G100 / LEON-G200 Data Sheet [6]).

Figure 1 illustrates an application circuit for the connection of LEON-G100-05S / LEON-G200-05S versions and LEON-G100-04S / LEON-G200-04S versions to a u-blox 3.0 V GNSS receiver, and Table 4 lists the suggested components:

- The **SDA** and **SCL** pins of the cellular module are directly connected to the corresponding pins of the u-blox 3.0 V GNSS receiver, with appropriate pull-up resistors connected to the 3.0 V GNSS supply rail, providing data communication between the cellular module and the GNSS receiver.
- The **GPIO2** pin is connected to the active-high enable pin (or the active-low shutdown pin) of the voltage regulator that supplies the u-blox GNSS receiver on the application board, providing the "GNSS supply enabled" function. A pull-down resistor is mounted on the **GPIO2** line to avoid switching on the GNSS receiver when the cellular module is switched off and its digital pins are tri-stated.
- The cellular module's **V_BCKP** supply output is connected to the GNSS receiver's **V_BCKP** backup supply input pin to supply its RTC and backup RAM when the **VCC** supply of the cellular module is within its operating range and the **VCC** supply of the GNSS receiver is switched off. This enables the u-blox GNSS receiver to recover from a power outage with either a hot start or a warm start (depending on the duration of the GNSS **VCC** outage) and to maintain the configuration settings saved in backup RAM.

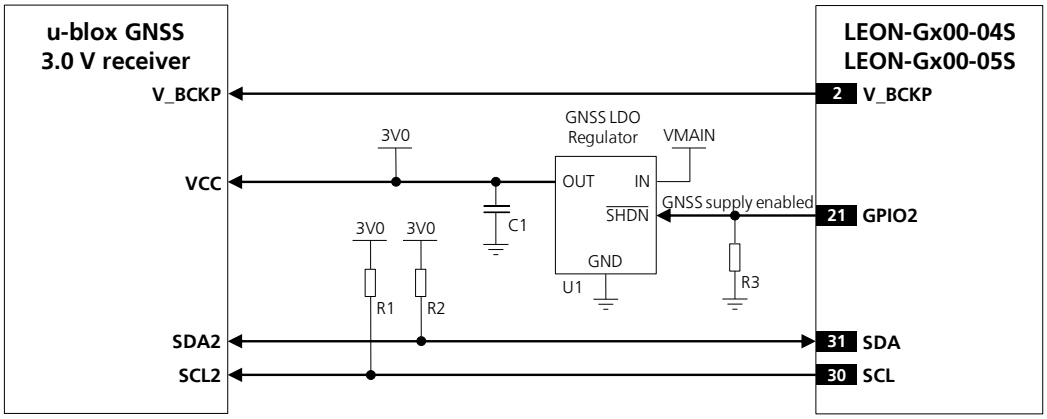

Figure 1: Application circuit for LEON-Gx00-05S and LEON-Gx00-04S versions and u-blox 3.0 V GNSS receiver

Reference	Description	Part Number - Manufacturer
R1, R2	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
U1	Voltage regulator for GNSS receiver	See GNSS receiver Hardware Integration Manual

Table 4: Components for LEON-Gx00-05S and LEON-Gx00-04S versions and u-blox 3.0 V GNSS receiver's application circuit

2.3.2 Application circuit for LEON-Gx00-06x and subsequent versions

☞ The pull-ups must be connected to a supply voltage of 3.0 V (typical), due to the voltage domain of the DDC (I^2C) pins of LEON-G100 / LEON-G200 series modules (for detailed electrical characteristics see LEON-G100 / LEON-G200 Data Sheet [7]).

Figure 2 illustrates the application circuit for the connection of LEON-G100-06x / LEON-G200-06S modules and subsequent versions to a u-blox 3.0 V GNSS receiver and Table 5 lists the suggested components:

- The **SDA** and **SCL** pins of the cellular module are directly connected to the corresponding pins of the u-blox 3.0 V GNSS receiver, with appropriate pull-up resistors connected to the 3.0 V GNSS supply rail, providing data communication between the cellular module and the GNSS receiver.
- The **GPIO2** pin is connected to the active-high enable pin (or the active-low shutdown pin) of the voltage regulator that supplies the u-blox GNSS receiver on the application board, providing the "GNSS supply enabled" function. A pull-down resistor is mounted on the **GPIO2** line to avoid switching on the GNSS receiver when the cellular module is switched off and its digital pins are tri-stated.
- The **GPIO3** pin is connected to the data ready output of the u-blox GNSS receiver (the **TxD1** pin of the GNSS receiver) on the application board, providing the "GNSS data ready" function.
- The **GPIO4** pin is connected to the synchronization timing input of the u-blox GNSS receiver (the **EXTINT0** pin of the GNSS receiver) on the application board, providing the "GNSS RTC sharing" function.
- The cellular module's **V_BCKP** supply output is connected to the GNSS receiver's **V_BCKP** backup supply input pin to supply its RTC and backup RAM when the **VCC** supply of the cellular module is within its operating range and the **VCC** supply of the GNSS receiver is switched off. This enables the u-blox GNSS receiver to recover from a power outage with either a hot start or a warm start (depending on the duration of the GNSS **VCC** outage) and to maintain the configuration settings saved in backup RAM.

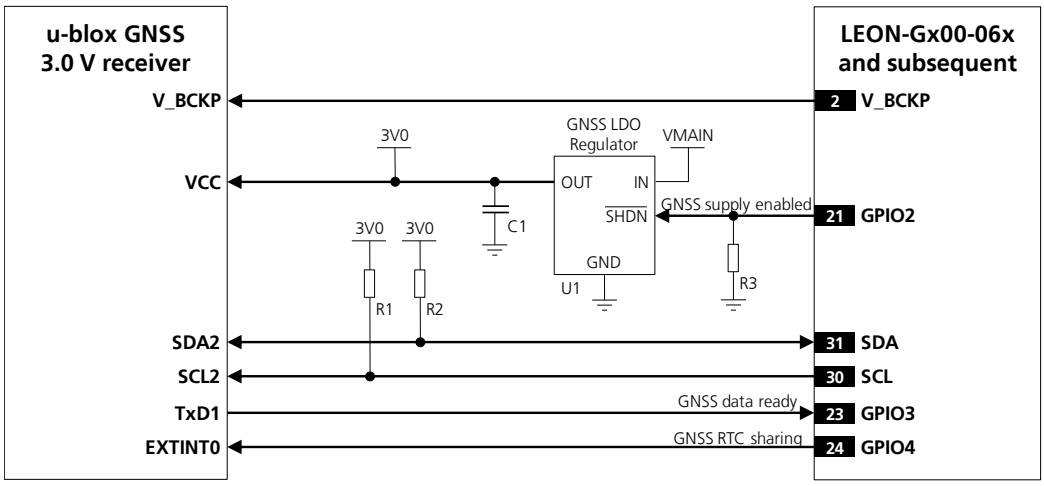

Figure 2: Application circuit for LEON-G100-06x / LEON-G200-06S cellular modules (and subsequent versions) and u-blox 3.0 V GNSS receivers

Reference	Description	Part Number – Manufacturer
R1, R2	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L – Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
U1	Voltage Regulator for GNSS receiver	See GNSS receiver Hardware Integration Manual

Table 5: Components for LEON-G100-06x / LEON-G200-06S cellular modules (and subsequent versions) and u-blox 3.0 V GNSS receivers' application circuit

2.4 Hardware architecture with LISA-U series

☞ Provide external pull-up resistors (e.g. 4.7 kΩ) on **SDA** and **SCL** lines and connect them to the **V_INT** 1.8 V supply source, or another proper supply source enabled after **V_INT** (e.g., as the 1.8 V GNSS supply rail present in the application circuits of Figure 3, Figure 4 or Figure 5, controlled by the cellular module). For detailed electrical characteristics see LISA-U1 series Data Sheet [8] or LISA-U2 series Data Sheet [15].

Figure 3 shows an application circuit connecting a LISA-U module to a u-blox 1.8 V GNSS receiver, and Table 6 lists the recommended components:

- The **SDA** and **SCL** pins of the cellular module are directly connected to the corresponding pins of the u-blox 1.8 V GNSS receiver, with the appropriate pull-up resistors connected to the 1.8 V GNSS supply rail, providing data communication between the cellular module and the GNSS receiver.
- The **GPIO2** pin is connected to the active-high enable pin (or the active-low shutdown pin) of the voltage regulator that supplies the u-blox GNSS receiver on the application board, providing the "GNSS supply enabled" function. A pull-down resistor is mounted on the **GPIO2** line to avoid switching on the GNSS receiver when the cellular module is switched off and its digital pins are tri-stated.
- The **GPIO3** pin is connected to the data ready output of the u-blox GNSS receiver (the **TxD1** pin of the u-blox GNSS receiver) on the application board, providing the "GNSS data ready" function.
- The **GPIO4** pin is connected to the synchronization timing input of the u-blox GNSS receiver (the **EXTINT0** pin of the GNSS receiver) on the application board, providing the "GNSS RTC sharing" function. An external pull-down resistor is mounted on the **GPIO4** line for correct "GNSS RTC sharing" function implementation.
- The cellular module's **V_BCKP** supply output is connected to the GNSS receiver's **V_BCKP** backup supply input pin to supply its RTC and backup RAM when the **VCC** supply of the cellular module is within its operating range and the **VCC** supply of the GNSS receiver is switched off. This enables the u-blox GNSS receiver to recover from a power outage with either a hot start or a warm start (depending on the duration of the GNSS **VCC** outage) and to maintain the configuration settings saved in backup RAM.

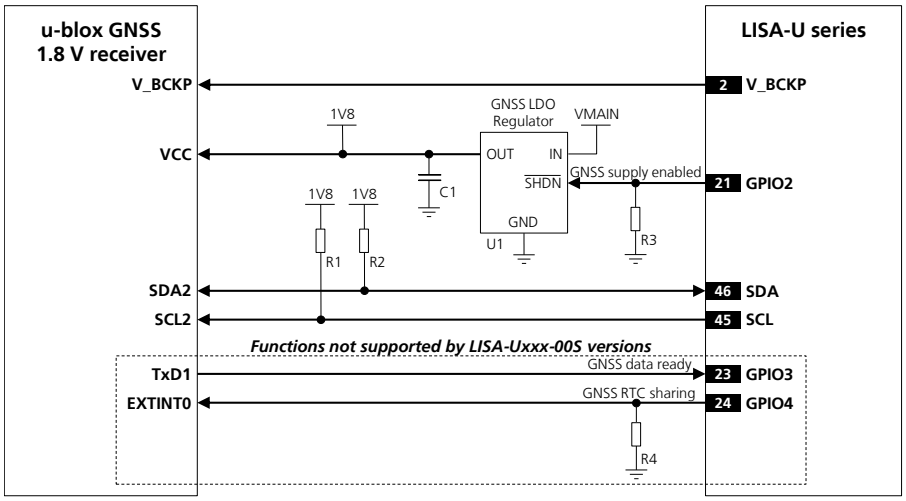

Figure 3: Application circuit for LISA-U series modules and u-blox 1.8 V GNSS receivers

Reference	Description	Part Number – Manufacturer
R1, R2, R4	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L – Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
U1	Voltage regulator for GNSS receiver	See GNSS receiver Hardware Integration Manual

Table 6: Components for LISA-U series modules and u-blox 1.8 V GNSS receivers' application circuit

Figure 4 illustrates an alternative solution as supply for a u-blox 1.8 V GNSS receiver: the **V_INT** supply output of LISA-U series cellular modules can be used to supply a u-blox 1.8 V GNSS receiver of the u-blox 6 platform (or any later u-blox platform) instead of using an external voltage regulator as shown in Figure 3. The **V_INT** supply is able to withstand the maximum current consumption of these positioning receivers.

The internal switching step-down regulator that generates the **V_INT** supply is set to 1.8 V (typical) when the LISA-U series cellular module is switched on and it is disabled when the module is switched off or when the **RESET_N** pin is forced at the low level.

The supply of the u-blox 1.8 V GNSS receiver can be switched off using an external p-channel MOSFET controlled by the **GPIO2** pin by means of a proper inverting transistor as shown in Figure 4, providing the "GNSS supply enable" function. If this feature is not required, the **V_INT** supply output can be directly connected to the u-blox 1.8 V GNSS receiver, so that it will be switched on when **V_INT** output is enabled.

The **V_INT** supply output provides low voltage ripple (up to 15 mVpp) when the module is in active-mode or in connected-mode, but it provides higher voltage ripple (up to 70 mVpp) when the module is in the low power idle-mode with power saving configuration enabled by AT+UPSV (see the u-blox AT Commands Manual [1]).

According to the voltage ripple characteristic of the **V_INT** supply output:

- The power saving configuration cannot be enabled to properly supply by **V_INT** output any 1.8 V GNSS receiver of the u-blox 6 platform and any 1.8 V GNSS receiver of the u-blox 7 or later platform with TCXO.
- The power saving configuration can be enabled to properly supply by **V_INT** output any 1.8 V GNSS receiver of the u-blox 7 or later platform without TCXO.
- Additional filtering may be needed to properly supply an external LNA, depending on the characteristics of the used LNA, adding a series ferrite bead and a bypass capacitor (e.g. the Murata BLM15HD182SN1 ferrite bead and the Murata GRM1555C1H220J 22 pF capacitor) at the input of the external LNA supply line.

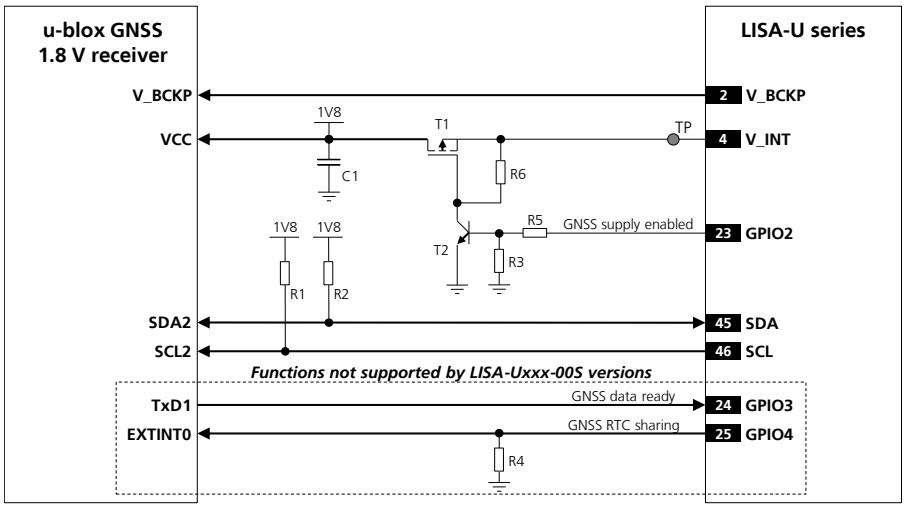

Figure 4: Application circuit for LISA-U series modules and u-blox 1.8 V GNSS receivers using V_INT as supply source

Reference	Description	Part Number - Manufacturer
R1, R2, R4	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
R5	10 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0710KL - Yageo Phycomp
R6	100 kΩ Resistor 0402 5% 0.1 W	RC0402JR-07100KL - Yageo Phycomp
T1	P-Channel MOSFET Low On-Resistance	IRLML6401 - International Rectifier or NTZS3151P - ON Semi
T2	NPN BJT Transistor	BC847 - Infineon
C1	100 nF Capacitor Ceramic X7R 0402 10% 16 V	GRM155R71C104KA01 - Murata

Table 7: Components for LISA-U modules and u-blox 1.8 V GNSS receivers' application circuit using V_INT as supply source

Figure 5 shows an application circuit connecting a LISA-U cellular module to a u-blox 3.0 V GNSS receiver, while Table 8 lists the recommended components:

- As the **SDA** and **SCL** pins of the LISA-U series modules are not compatible with 3.0 V logic levels, the connection to the related I²C pins of the u-blox 3.0 V GNSS receiver must be provided using a proper I²C-bus Bidirectional Voltage Translator (e.g. TI TCA9406, which additionally provides the partial power down feature so that the GNSS 3.0 V supply can be ramped up before the **V_INT** 1.8 V cellular supply), with proper pull-up resistors
- The **GPIO2** pin is connected to the active-high enable pin of the external voltage regulator that supplies the u-blox 3.0 V GNSS receiver to enable or disable the 3.0 V GNSS supply
- As the **GPIO3** and **GPIO4** pins of the LISA-U series modules are not compatible with 3.0 V logic levels, the connection to the related pins of the u-blox 3.0 V GNSS receiver must be provided using a proper Unidirectional General Purpose Voltage Translator (e.g. TI SN74AVC2T245, which additionally provides the partial power down feature so that the 3.0 V GNSS supply can be also ramped up before the **V_INT** 1.8 V cellular supply)
- The **V_BCKP** supply output of the cellular module is directly connected to the **V_BCKP** backup supply input of the u-blox 3.0 V GNSS receiver as in the application circuit for a u-blox 1.8 V GNSS receiver

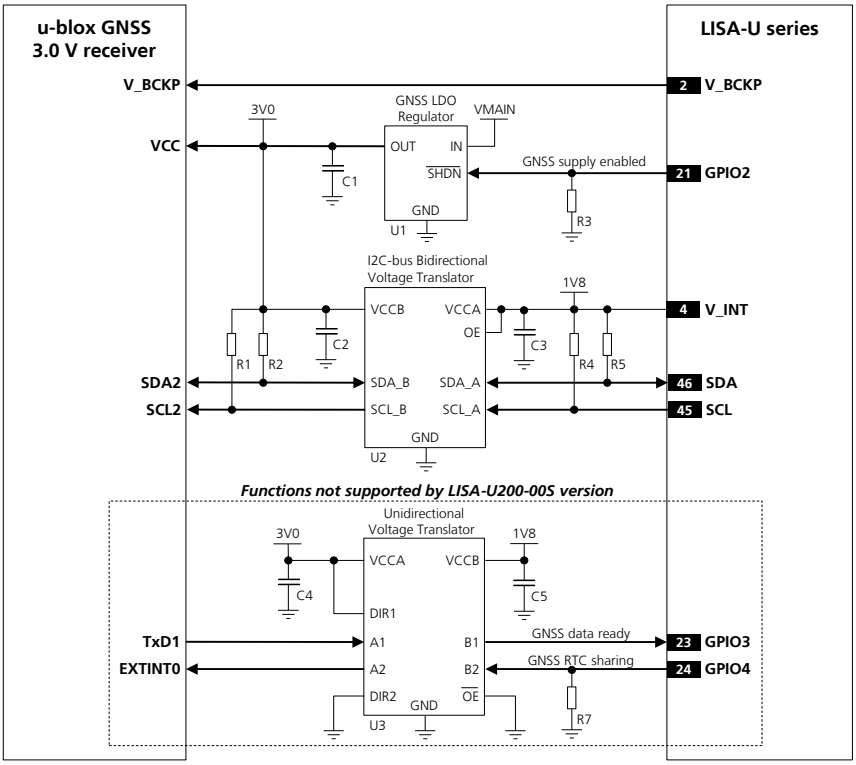

Figure 5: Application circuit for LISA-U series modules and u-blox 3.0 V GNSS receivers

Reference	Description	Part Number – Manufacturer
R1, R2, R4, R5, R7	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L – Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
R6	200 kΩ Resistor 0402 5% 0.1 W	RC0402JR-07200KL - Yageo Phycomp
C2, C3, C4, C5	100 nF Capacitor Ceramic X5R 0402 10% 10V	GRM155R71C104KA01 - Murata
U1, C1	Voltage regulator for GNSS receiver and related output bypass capacitor	See GNSS receiver Hardware Integration Manual
U2	I2C-bus Bidirectional Voltage Translator	TCA9406DCUR - Texas Instruments
U3	Generic Bidirectional Voltage Translator	SN74AVC2T245 - Texas Instruments

Table 8: Components for LISA-U series cellular modules and u-blox 3.0 V GNSS receivers' application circuit

2.5 Hardware architecture with LISA-C200 series

☞ Provide external pull-up resistors (e.g. 4.7 kΩ) on **SDA** and **SCL** lines and connect them to the **V_INT** 1.8 V supply source, or another proper supply source enabled after **V_INT** (e.g., as the 1.8 V GNSS supply rail present in the application circuits of Figure 6 or Figure 7, controlled by the cellular module). For detailed electrical characteristics see LISA-C200 Data Sheet [16].

Figure 6 shows an application circuit connecting a LISA-C200 cellular module to a u-blox 1.8 V GNSS receiver, and Table 9 lists the recommended components:

- The **SDA** and **SCL** pins of the cellular module are directly connected to the corresponding pins of the u-blox 1.8 V GNSS receiver, with the appropriate pull-up resistors connected to the 1.8 V GNSS supply rail, providing data communication between the cellular module and the GNSS receiver.
- The **GPIO2** pin is connected to the active-high enable pin (or the active-low shutdown pin) of the voltage regulator that supplies the u-blox GNSS receiver on the application board, providing the "GNSS supply enabled" function. A pull-down resistor is mounted on the **GPIO2** line to avoid switching on the GNSS receiver when the cellular module is switched off and its digital pins are tri-stated.
- The **GPIO3** pin is connected to the data ready output of the u-blox GNSS receiver (the **TxD1** pin of the u-blox GNSS receiver) on the application board, providing the "GNSS data ready" function.
- The **GPIO4** pin is connected to the synchronization timing input of the u-blox GNSS receiver (the **EXTINT0** pin of the GNSS receiver) on the application board, as the **GPIO4** hardware is designed to implement the "GNSS RTC sharing" function. In the current software release, this function is not enabled yet.
- The cellular module's **V_INT** supply output is connected to the GNSS receiver's **V_BCKP** backup supply input pin to supply its RTC and backup RAM when the cellular module is switched on and the **VCC** supply of the GNSS receiver is switched off. This enables the u-blox GNSS receiver to recover from a power outage with either a hot start or a warm start (depending on the duration of the GNSS **VCC** outage) and to maintain the configuration settings saved in backup RAM.

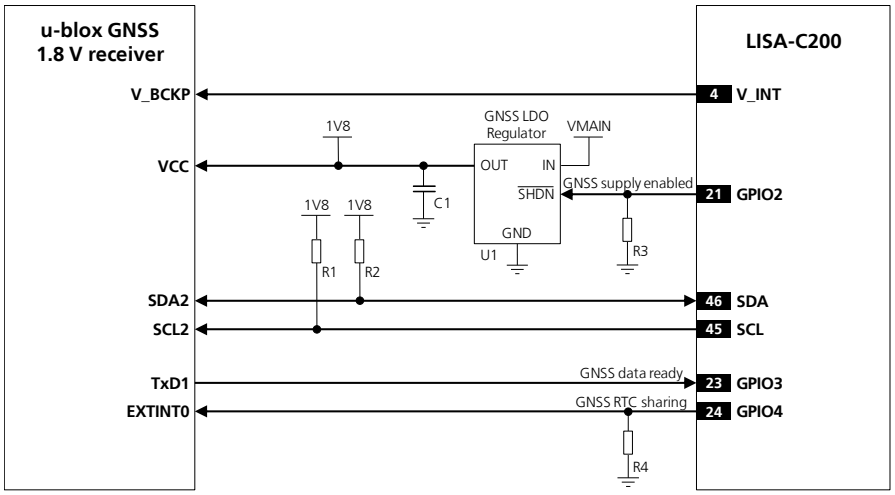

Figure 6: Application circuit for LISA-C200 modules and u-blox 1.8 V GNSS receivers using V_INT as supply source

Reference	Description	Part Number – Manufacturer
R1, R2, R4	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L – Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
U1	Voltage regulator for GNSS receiver	See GNSS receiver Hardware Integration Manual

Table 9: Components for LISA-C200 modules and u-blox 1.8 V GNSS receivers' application circuit

Figure 7 shows an application circuit connecting a LISA-C200 cellular module to a u-blox 3.0 V GNSS receiver, while Table 10 lists the recommended components:

- As the **SDA** and **SCL** pins of the LISA-C200 modules are not compatible with 3.0 V logic levels, the connection to the related I²C pins of the u-blox 3.0 V GNSS receiver must be provided using a proper I²C-bus Bidirectional Voltage Translator (e.g. TI TCA9406, which additionally provides the partial power down feature so that the GNSS 3.0 V supply can be ramped up before the **V_INT** 1.8 V cellular supply), with proper pull-up resistors
- The **GPIO2** pin is connected to the active-high enable pin of the external voltage regulator that supplies the u-blox 3.0 V GNSS receiver to enable or disable the 3.0 V GNSS supply
- As the **GPIO3** and **GPIO4** pins of the LISA-C200 modules are not compatible with 3.0 V logic levels, the connection to the related pins of the u-blox 3.0 V GNSS receiver must be provided using a proper Unidirectional General Purpose Voltage Translator (e.g. TI SN74AVC2T245, which additionally provides the partial power down feature so that the 3.0 V GNSS supply can be also ramped up before the **V_INT** 1.8 V cellular supply)
- The **V_INT** supply output of the cellular module is directly connected to the **V_BCKP** backup supply input of the u-blox 3.0 V GNSS receiver as in the application circuit for a u-blox 1.8 V GNSS receiver

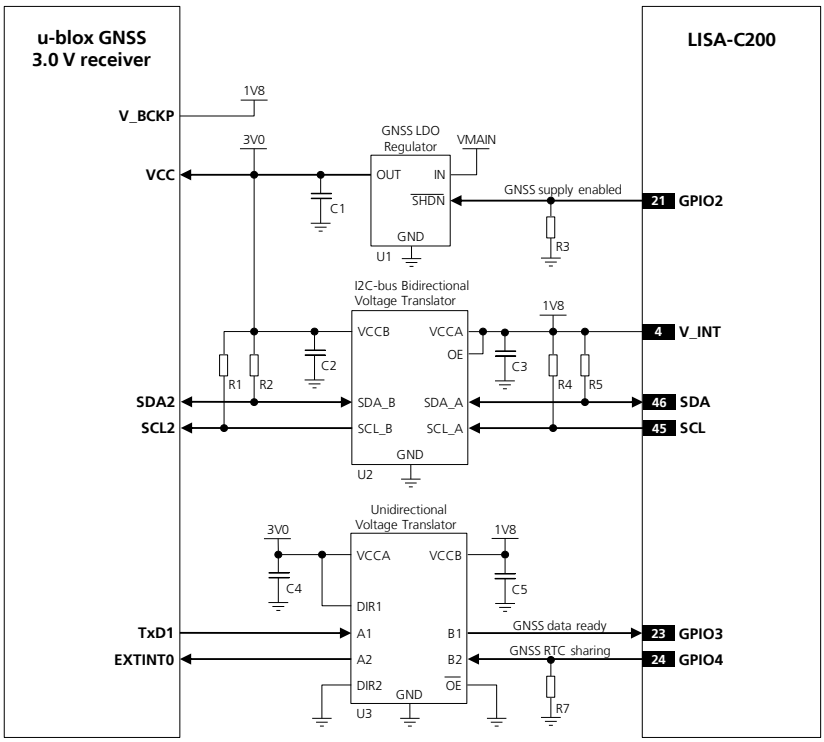

Figure 7: Application circuit for LISA-C200 modules and u-blox 3.0 V GNSS receivers

Reference	Description	Part Number – Manufacturer
R1, R2, R4, R5, R7	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L – Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
R6	200 kΩ Resistor 0402 5% 0.1 W	RC0402JR-07200KL - Yageo Phycomp
C2, C3, C4, C5	100 nF Capacitor Ceramic X5R 0402 10% 10V	GRM155R71C104KA01 - Murata
U1, C1	Voltage regulator for GNSS receiver and related output bypass capacitor	See GNSS receiver Hardware Integration Manual
U2	I2C-bus Bidirectional Voltage Translator	TCA9406DCUR - Texas Instruments
U3	Generic Bidirectional Voltage Translator	SN74AVC2T245 - Texas Instruments

Table 10: Components for LISA-C200 cellular modules and u-blox 3.0 V GNSS receivers' application circuit

2.6 Hardware architecture with SARA-G340 / SARA-G350 series

Provide external pull-up resistors (e.g. 4.7 kΩ) on **SDA** and **SCL** lines and connect them to the **V_INT** 1.8 V supply source, or another proper supply source enabled after **V_INT** (e.g., as the 1.8 V or 3.0 V GNSS supply rail present in the application circuits of Figure 8, Figure 9 or Figure 10, controlled by the cellular module). For detailed electrical characteristics see the SARA-G3 series Data Sheet [17].

Figure 8 illustrates an application circuit for the SARA-G340 / SARA-G350 connection to a u-blox 1.8 V GNSS receiver:

- The **SDA** and **SCL** pins of the cellular module are directly connected to the corresponding pins of the u-blox 1.8 V GNSS receiver, with appropriate pull-up resistors connected to the 1.8 V GNSS supply rail, providing data communication between the cellular module and the GNSS receiver
- The **GPIO2** pin is connected to the active-high enable pin (or the active-low shutdown pin) of the voltage regulator that supplies the u-blox GNSS receiver on the application board, providing the "GNSS supply enabled" function. A pull-down resistor is mounted on the **GPIO2** line to avoid switching on the GNSS receiver when the cellular module is switched off and its digital pins are tri-stated
- The **GPIO3** pin is connected to the data ready output of the u-blox GNSS receiver (the **TxD1** pin of the u-blox GNSS receiver) on the application board, providing the "GNSS data ready" function
- The **GPIO4** pin is connected to the synchronization timing input of the u-blox GNSS receiver (the **EXTINT0** pin of the GNSS receiver) on the application board, providing "GNSS RTC sharing" function.
- The cellular module's **V_BCKP** supply output is connected to the GNSS receiver's **V_BCKP** backup supply input pin to supply its RTC and backup RAM when the **VCC** supply of the cellular module is within its operating range and the **VCC** supply of the GNSS receiver is switched off. This enables the u-blox GNSS receiver to recover from a power outage with either a hot start or a warm start (depending on the duration of the GNSS **VCC** outage) and to maintain the configuration settings saved in backup RAM

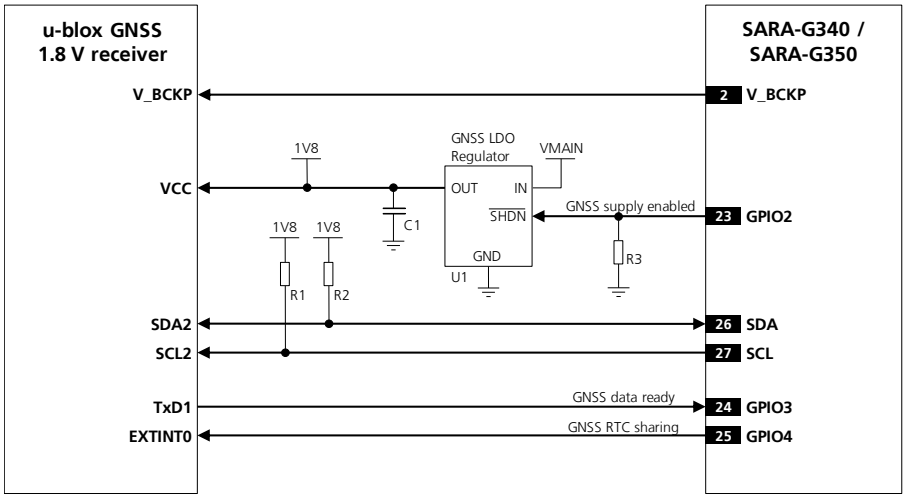

Figure 8: Application circuit for SARA-G340 / SARA-G350 modules and u-blox 1.8 V GNSS receivers

Reference	Description	Part Number - Manufacturer
R1, R2	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
U1	Voltage regulator for GNSS receiver	See GNSS receiver Hardware Integration Manual

Table 11: Components for SARA-G340 / SARA-G350 modules and u-blox 1.8 V GNSS receivers' application circuit

Figure 9 illustrates an alternative solution as supply for a u-blox 1.8 V GNSS receiver: the **V_INT** supply output of SARA-G340 / SARA-G350 cellular modules can be used to supply a u-blox 1.8 V GNSS receiver of the u-blox 6 platform (or any later u-blox platform) instead of using an external voltage regulator as shown in Figure 8. The **V_INT** supply is able to withstand the maximum current consumption of these positioning receivers.

The internal switching step-down regulator that generates the **V_INT** supply is set to 1.8 V (typical) when the SARA-G340 / SARA-G350 cellular module is switched on and it is disabled when the module is switched off.

The supply of the u-blox 1.8 V GNSS receiver can be switched off using an external p-channel MOSFET controlled by the **GPIO2** pin by means of a proper inverting transistor, as shown in Figure 9, providing the "GNSS supply enable" function. If this feature is not required, the **V_INT** supply output can be directly connected to the u-blox 1.8 V GNSS receiver, so that it will be switched on when **V_INT** output is enabled.

The **V_INT** supply output provides low voltage ripple (up to 15 mVpp) when the module is in active-mode or in connected-mode, but it provides higher voltage ripple (up to 90 mVpp) when the module is in the low power idle-mode with power saving configuration enabled by AT+UPSV (see the u-blox AT Commands Manual [1]).

According to the voltage ripple characteristic of the **V_INT** supply output:

- The power saving configuration cannot be enabled to use **V_INT** output to properly supply any 1.8 V GNSS receiver of the u-blox 6 platform and any 1.8 V GNSS receiver of the u-blox 7 or later platform with TCXO.
- The power saving configuration can be enabled to use **V_INT** output to properly supply any 1.8 V GNSS receiver of the u-blox 7 or later platform without TCXO.
- Additional filtering may be needed to properly supply an external LNA, depending on the characteristics of the used LNA, adding a series ferrite bead and a bypass capacitor (e.g. the Murata BLM15HD182SN1 ferrite bead and the Murata GRM1555C1H220J 22 pF capacitor) at the input of the external LNA supply line.

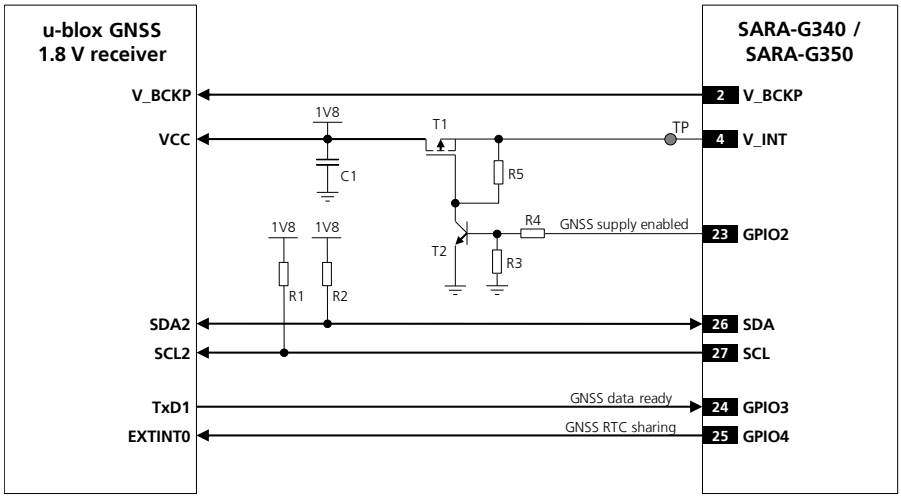

Figure 9: Application circuit for SARA-G340 / SARA-G350 modules and u-blox 1.8 V GNSS receivers using V_INT as supply source

Reference	Description	Part Number - Manufacturer
R1, R2	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
R4	10 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0710KL - Yageo Phycomp
R5	100 kΩ Resistor 0402 5% 0.1 W	RC0402JR-07100KL - Yageo Phycomp
T1	P-Channel MOSFET Low On-Resistance	IRLML6401 - International Rectifier or NTZS3151P - ON Semi
T2	NPN BJT Transistor	BC847 - Infineon
C1	100 nF Capacitor Ceramic X7R 0402 10% 16 V	GRM155R71C104KA01 - Murata

Table 12: Components for SARA-G340 / SARA-G350 and u-blox 1.8 V GNSS receivers' application circuit using V_INT as supply

Figure 10 illustrates the application circuit for the SARA-G340 / SARA-G350 connection to a u-blox 3.0 V GNSS receiver:

- The **SDA** and **SCL** pins of SARA-G340 / SARA-G350 are directly connected to the corresponding pins of the u-blox 3.0 V GNSS receiver, with the appropriate pull-up resistors on the 3.0 V voltage rail. An I^2C-bus voltage translator is not needed because the DDC (I^2C) pins of the SARA-G340 / SARA-G350 modules are capable up to 3.3 V.
- The **GPIO2** is connected to the active-high enable pin of the external voltage regulator that supplies the u-blox 3.0 V GNSS receiver to enable or disable the 3.0 V GNSS supply.
- As the **GPIO3** and **GPIO4** pins of SARA-G340 / SARA-G350 modules are not compatible with 3.0 V logic levels, the connection to the related pins of the u-blox 3.0 V GNSS receiver must be provided using a proper Unidirectional Voltage Translator (e.g. TI SN74AVC2T245, which additionally provides the partial power down feature so that the 3.0 V GNSS supply can be also ramped up before the **V_INT** 1.8 V cellular supply).
- The **V_BCKP** supply output of the cellular module is directly connected to the **V_BCKP** backup supply input of the u-blox 3.0 V GNSS receiver as in the application circuit for a u-blox 1.8 V GNSS receiver.

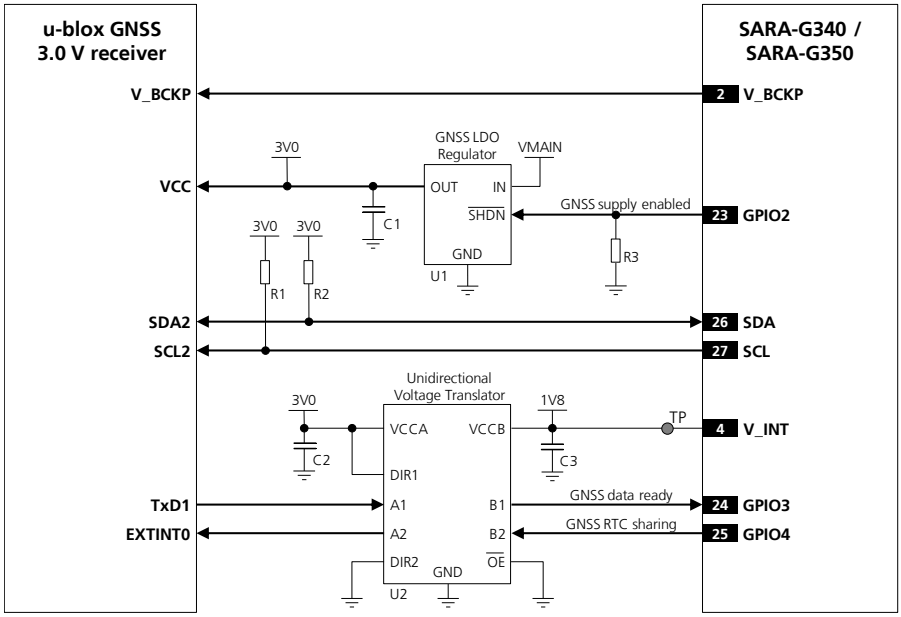

Figure 10: Application circuit for SARA-G340 / SARA-G350 modules and u-blox 3.0 V GNSS receivers

Reference	Description	Part Number – Manufacturer
R1, R2	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
C2, C3	100 nF Capacitor Ceramic X5R 0402 10% 10V	GRM155R71C104KA01 - Murata
U1	Voltage regulator for GNSS receiver	See GNSS receiver Hardware Integration Manual
U2	Generic Unidirectional Voltage Translator	SN74AVC2T245 - Texas Instruments

Table 13: Components for SARA-G340 / SARA-G350 modules and u-blox 3.0 V GNSS receivers' application circuit

2.7 Hardware architecture with SARA-U2 series

☞ Provide external pull-up resistors (e.g. 4.7 kΩ) on **SDA** and **SCL** lines and connect them to the **V_INT** 1.8 V supply source, or another proper supply source enabled after **V_INT** (e.g., as the 1.8 V or 3.0 V GNSS supply rail present in the application circuits of Figure 11, Figure 12 or Figure 13, controlled by the cellular module). For detailed electrical characteristics see the SARA-U2 series Data Sheet [21].

Figure 11 illustrates an application circuit for the SARA-U2 connection to a u-blox 1.8 V GNSS receiver:

- The **SDA** and **SCL** pins of the cellular module are directly connected to the corresponding pins of the u-blox 1.8 V GNSS receiver, with appropriate pull-up resistors connected to the 1.8 V GNSS supply rail, providing data communication between the cellular module and the GNSS receiver
- The **GPIO2** pin is connected to the active-high enable pin (or the active-low shutdown pin) of the voltage regulator that supplies the u-blox GNSS receiver on the application board, providing the "GNSS supply enabled" function. A pull-down resistor is mounted on the **GPIO2** line to avoid switching on the GNSS receiver when the cellular module is switched off and its digital pins are tri-stated
- The **GPIO3** pin is connected to the data ready output of the u-blox GNSS receiver (the **TxD1** pin of the u-blox GNSS receiver) on the application board, providing the "GNSS data ready" function
- The **GPIO4** pin is connected to the synchronization timing input of the u-blox GNSS receiver (the **EXTINT0** pin of the GNSS receiver) on the application board, providing "GNSS RTC sharing" function.
- The cellular module's **V_BCKP** supply output is connected to the GNSS receiver's **V_BCKP** backup supply input pin to supply its RTC and backup RAM when the **VCC** supply of the cellular module is within its operating range and the **VCC** supply of the GNSS receiver is switched off. This enables the u-blox GNSS receiver to recover from a power outage with either a hot start or a warm start (depending on the duration of the GNSS **VCC** outage) and to maintain the configuration settings saved in backup RAM

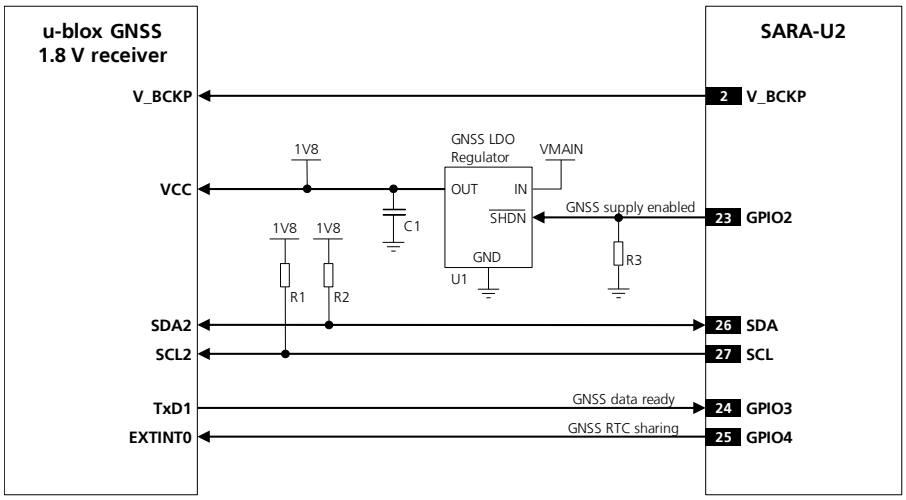

Figure 11: Application circuit for SARA-U2 modules and u-blox 1.8 V GNSS receivers

Reference	Description	Part Number - Manufacturer
R1, R2	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
U1	Voltage regulator for GNSS receiver	See GNSS receiver Hardware Integration Manual

Table 14: Components for SARA-U2 modules and u-blox 1.8 V GNSS receivers' application circuit

Figure 12 illustrates an alternative solution as supply for a u-blox 1.8 V GNSS receiver: the **V_INT** supply output of SARA-U2 cellular modules can be used to supply a u-blox 1.8 V GNSS receiver of the u-blox 6 platform (or any later u-blox platform) instead of using an external voltage regulator as shown in Figure 11. The **V_INT** supply is able to withstand the maximum current consumption of these positioning receivers.

The internal switching step-down regulator that generates the **V_INT** supply is set to 1.8 V (typical) when the SARA-U2 cellular module is switched on and it is disabled when the module is switched off.

The supply of the u-blox 1.8 V GNSS receiver can be switched off using an external p-channel MOSFET controlled by the **GPIO2** pin by means of a proper inverting transistor as shown in Figure 12, providing the "GNSS supply enable" function. If this feature is not required, the **V_INT** supply output can be directly connected to the u-blox 1.8 V GNSS receiver, so that it will be switched on when **V_INT** output is enabled.

The **V_INT** supply output provides low voltage ripple (up to 15 mVpp) when the module is in active-mode or in connected-mode, but it provides higher voltage ripple (up to 90 mVpp) when the module is in the low power idle-mode with power saving configuration enabled by AT+UPSV (see the u-blox AT Commands Manual [1]).

According to the voltage ripple characteristic of the **V_INT** supply output:

- The power saving configuration cannot be enabled to use **V_INT** output to properly supply any 1.8 V GNSS receiver of the u-blox 6 platform and any 1.8 V GNSS receiver of the u-blox 7 or later platform with TCXO.
- The power saving configuration can be enabled to use **V_INT** output to properly supply any 1.8 V GNSS receiver of the u-blox 7 or later platform without TCXO.
- Additional filtering may be needed to properly supply an external LNA, depending on the characteristics of the used LNA, adding a series ferrite bead and a bypass capacitor (e.g. the Murata BLM15HD182SN1 ferrite bead and the Murata GRM1555C1H220J 22 pF capacitor) at the input of the external LNA supply line.

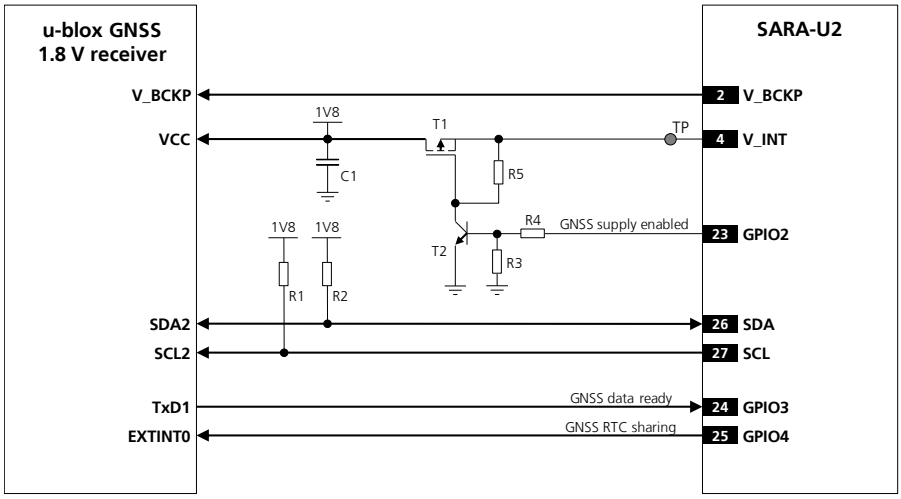

Figure 12: Application circuit for SARA-U2 modules and u-blox 1.8 V GNSS receivers using V_INT as supply source

Reference	Description	Part Number - Manufacturer
R1, R2	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
R4	10 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0710KL - Yageo Phycomp
R5	100 kΩ Resistor 0402 5% 0.1 W	RC0402JR-07100KL - Yageo Phycomp
T1	P-Channel MOSFET Low On-Resistance	IRLML6401 - International Rectifier or NTZS3151P - ON Semi
T2	NPN BJT Transistor	BC847 - Infineon
C1	100 nF Capacitor Ceramic X7R 0402 10% 16 V	GRM155R71C104KA01 - Murata

Table 15: Components for SARA-U2 and u-blox 1.8 V GNSS receivers' application circuit using V_INT as supply source

Figure 13 illustrates the application circuit for the SARA-U2 connection to a u-blox 3.0 V GNSS receiver:

- As the **SDA** and **SCL** pins of the SARA-U2 cellular module are not compatible with 3.0 V logic levels, the connection to the related I²C pins of the u-blox 3.0 V GNSS receiver must be provided using a proper I²C-bus Bidirectional Voltage Translator (e.g. TI TCA9406, which additionally provides the partial power down feature so that the GNSS 3.0 V supply can be ramped up before the **V_INT** 1.8 V cellular supply), with proper pull-up resistors.
- The **GPIO2** is connected to the active-high enable pin of the external voltage regulator that supplies the u-blox 3.0 V GNSS receiver to enable or disable the 3.0 V GNSS supply.
- As the **GPIO3** and **GPIO4** pins of the SARA-U2 cellular modules are not compatible with 3.0 V logic levels, the connection to the related pins of the u-blox 3.0 V GNSS receiver must be provided using a proper Unidirectional General Purpose Voltage Translator (e.g. TI SN74AVC2T245, which additionally provides the partial power down feature so that the 3.0 V GNSS supply can be also ramped up before the **V_INT** 1.8 V cellular supply).
- The **V_BCKP** supply output of the cellular module is directly connected to the **V_BCKP** backup supply input of the u-blox 3.0 V GNSS receiver as in the application circuit for a u-blox 1.8 V GNSS receiver.

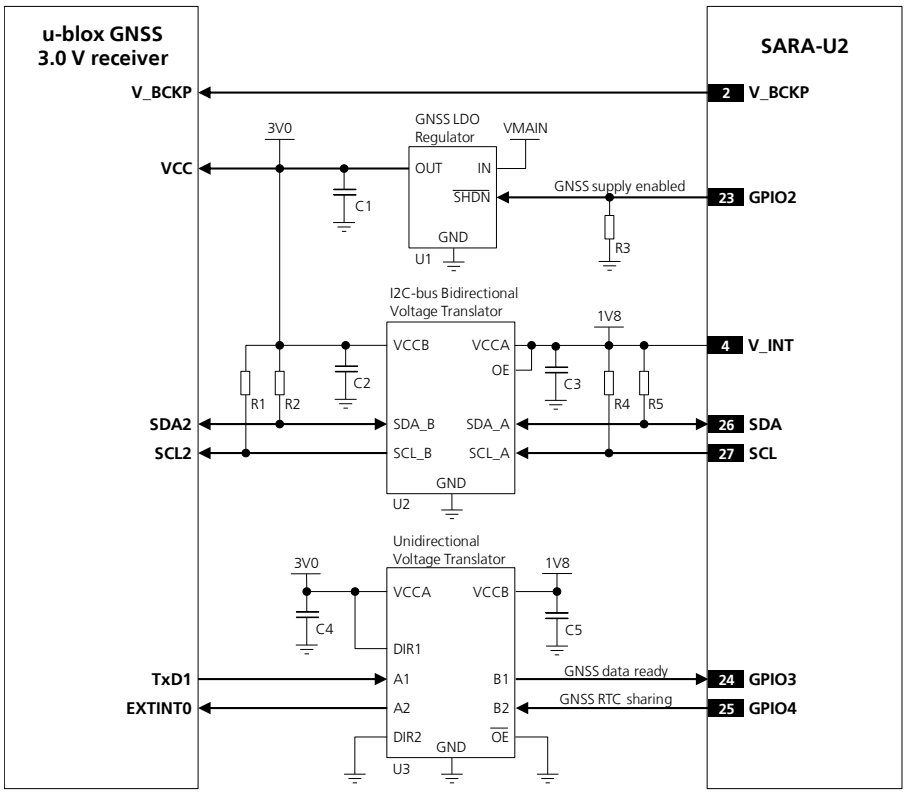

Figure 13: Application circuit for SARA-U2 modules and u-blox 3.0 V GNSS receivers

Reference	Description	Part Number – Manufacturer
R1, R2, R4, R5	4.7 kΩ Resistor 0402 5% 0.1 W	RC0402JR-074K7L - Yageo Phycomp
R3	47 kΩ Resistor 0402 5% 0.1 W	RC0402JR-0747KL - Yageo Phycomp
C2, C3, C4, C5	100 nF Capacitor Ceramic X5R 0402 10% 10V	GRM155R71C104KA01 - Murata
U1, C1	Voltage Regulator for GNSS receiver and related output bypass capacitor	See GNSS receiver Hardware Integration Manual
U2	I2C-bus Bidirectional Voltage Translator	TCA9406DCUR - Texas Instruments
U3	Generic Unidirectional Voltage Translator	SN74AVC2T245 - Texas Instruments

Table 16: Components for SARA-U2 modules and u-blox 3.0 V GNSS receivers' application circuit

2.8 Jamming and EMC considerations

When integrating a cellular module and a GNSS receiver in a single board, be aware of the following possible issues that may affect the GNSS receiver:

- Electro-Magnetic Compatibility (EMC)
- In-band and out-band jamming effect

EMC issues may arise in application board designs when harmonics of the cellular signals are radiated back through the GNSS antenna. In a handheld type design, an isolation of approximately 20 dB can be reached with careful placement of the antennas. If such isolation cannot be achieved, a SAW filter (or a ceramic band-pass filter) in front of the GNSS receiver should be integrated in the application board to reduce EMC issues.

For further design-in guidelines on how to prevent the generation of harmonics by cellular modules, follow all the recommendations reported in the corresponding cellular module System Integration Manual [4] [5] [18] [19], with particular attention to the module antenna RF interface and the module supply interface design.

In-band jamming is caused by a signal with frequencies within or close to the GNSS constellation frequency used, while out-band jamming is caused by a very strong signal with frequencies different from the GNSS carrier, that is picked up at the input of the GNSS receiver and that can saturate the receiver front-end, producing a reduction in the GNSS sensitivity.

The signals transmitted by cellular modules (GSM, GPRS, UMTS, CDMA or LTE) can be considered as sources of strong out-band power levels, and, if not properly taken into consideration, may lead to a degradation of the GNSS receiver performances.

Jamming, and in particular out-band jamming, is specifically important with cellular modules operating in UMTS, CDMA or LTE, since in these cases signals are continuously transmitted by the modules and these may ease the saturation process of the GNSS front-end. Differently, GSM and GPRS are TDMA technologies, signals are transmitted in bursts and GNSS receiver can recover during the not-transmitting (unused) bursts.

To solve the out-band jamming issue, the application board integrating the cellular module and the GNSS receiver should integrate a SAW filter (or a ceramic band-pass filter) in front of the GNSS receiver, and maintain a good grounding concept in the layout design.

Depending on the u-blox GNSS chip/module platform and variant, a SAW filter and/or an LNA can be built into the chip/module. GNSS receivers integrating an internal SAW filter or an LNA are less prone to the off-band jamming issue.

See the Data Sheet of the intended u-blox GNSS chip/receiver for a complete description of the built-in components and receiver performance.

For further design-in guidelines on how to prevent electromagnetic susceptibility issues on u-blox GNSS receivers, including measures against out-band jamming, follow all the recommendations reported in the corresponding u-blox GNSS receiver Hardware Integration Manual, with particular attention to the Electrical Overstress (EOS) and Electro-Magnetic Interference (EMI) precautions for applications with cellular modules.

3 Software architecture

The u-blox cellular module has full control over the positioning chip/module and can power it on and off, send and receive commands using proprietary UBX protocol and receive positioning information through NMEA strings.

⚠ **To avoid I²C interface lock in case of an external reset of the GNSS receiver during I²C communication, an automatic recovery mechanism is implemented. Nevertheless in case of a lock, a power-cycle of the cellular module is required to restore normal functionality.**

3.1 Multi-GNSS receivers support

u-blox multi GNSS receivers are capable of receiving and processing signals from multiple Global Navigation Satellite Systems (GNSS). These GNSS systems are currently supported:

- GPS – Global positioning system operated by USA
- GLONASS – Positioning system operated by Russia
- QZSS – Positioning system operated by Japan
- BeiDou – Positioning system operated by China

According to the configuration applied to the multi-GNSS receiver, the proper aiding information must be issued to the device.

Specific GNSS system can be activated using the (optional) third parameter of AT+UGPS command. If the connected GNSS receiver is not a multi-GNSS device, this parameter is ignored. If the connected GNSS receiver is a multi-GNSS device and the optional third parameter is omitted then the GPS GNSS system is configured as default.

The detection of the type of connected GNSS receiver is performed by the cellular module by polling for the UBX-MON-VER message as the very first step after GNSS is powered on with AT+UGPS command.

3.2 “GNSS data ready” function

By default the cellular module reads data from the I²C interface every 200 ms (polling mode) even if the GNSS receiver has no data to communicate. The “GNSS data ready” function is implemented to avoid polling the I²C bus when no data is available.

The “GNSS data ready” function improves the cellular module’s power consumption. If the AT+UPSV command enables the power saving in the cellular modules and the GNSS receiver does not send data by the DDC (I²C) interface, the module automatically enters low power idle-mode whenever possible. With the “GNSS data ready” function, the GNSS receiver indicates to the cellular module that it is ready to send data via the DDC (I²C) interface: the GNSS receiver can wake up the cellular module if it is in low power idle-mode, so that data sent by the GNSS receiver will not be lost by the cellular module even if power saving is enabled.

Use the AT+UGPRF command to enable this function, (see the u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20] for more details).

☞ With u-blox 6 GNSS receivers, when the GNSS is powered on, the GNSS UART1 is disabled and the **TxD1** pin is used to handle interrupts when data is available.

☞ Table 3 indicates which cellular modules support the function.

☞ The support of the "GNSS data ready" function can vary depending on the u-blox GNSS receiver version. Table 28 provides an overview of which GNSS receivers support this feature.

☞ Polling mode is automatically used when the GNSS receiver does not support this function.

☞ If the "GNSS data ready" function is not working (e.g. line not connected, wrong configuration, etc) the cellular module automatically switches back to polling mode. This fall back mechanism is not implemented on LEON-G100 / LEON-G200 series, so in this case the cellular module is not able to read data from the GNSS receiver.

3.3 Reading NMEA strings

u-blox cellular modules support reading NMEA strings from the GNSS receiver through the AT command port. Before being able to read a specific NMEA string, it is necessary to activate the storage of the last value of that particular NMEA string.

If the storing of a particular NMEA string was not activated, the information text response to the query will be "0,NULL".

The last value of a specific NMEA string is stored in RAM and is made available even after GNSS switch off.

The NMEA standard differentiates between GPS, GLONASS and multi-GNSS receivers using a different 'Talker ID'. Depending upon device model and system configuration, the u-blox receiver could output messages using any one of these Talker IDs. By default, the receivers configured to support GPS, SBAS and QZSS use the 'GP' Talker ID, receivers configured to support GLONASS use the 'GL' Talker ID, receivers configured to support BeiDou use the 'GB' Talker ID, and receivers configured for any combinations of multiple GNSS use the 'GN' Talker ID.

Even if the NMEA specification indicates that the GGA message is GPS specific, u-blox receivers support the output of a GGA message for each of the Talker IDs.

When reading an NMEA message, if the information text response is "1,Not available" then the storing of the NMEA string is activated but this information has not been still sent to the user, if this persist check that the relative NMEA message is enabled. To enable it use the +UGUBX command (for further information see the UBX-CFG-MSG message in the u-blox GNSS Protocol Specification).

☞ For a complete list of supported NMEA strings as well as the corresponding commands description, see the u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20], +UGZDA, +UGGGA, +UGGLL, +UGGSV, +UGRMC, +UGVTG, +UGGSA commands.

Command	Response	Description
AT+UGRMC=1	OK	Activate storing of the last value of $RMC NMEA string.
AT+UGZDA=1	OK	Activate storing of the last value of $ZDA NMEA string.
AT+UGIND=1	OK	Activate the unsolicited aiding result.
AT+UGPS=1,1,67	OK	Start the GNSS with GPS+SBAS+GLONASS systems and local aiding.
	+UUGIND: 0,67	URC reporting GNSS system activated.
	+UUGIND: 1,0	URC reporting GPS mode "Local Aiding" ("1") and "No error" ("0").
AT+UGRMC?	+UGRMC: 1,$GNRMC,141247.00,A,4542.84560,N,01344.46384,E,0.007,,280514,,,D*64 OK	Read the last stored value of the NMEA $RMC string. Talker ID is 'GN' because of the combination of multiple GNSS.
AT+UGZDA?	+UGZDA: 1,$GNZDA,... OK	Read the last stored value of the NMEA $ZDA string.
AT+UGPS=0	OK	Stop the GNSS.
	+UUGIND: 1,0	URC reporting GPS mode "Local Aiding" ("1") and "No error" ("0").

Command	Response	Description
AT+UGRMC?	+UGRMC: 1,$GNRMC,141247.00,A,4542.84560,N,01344.46384,E,0.007,,280514,,,D*64 OK	Read the last string of the NMEA $RMC string. ☞ The GNSS is switched off, this string is the last one saved while the GNSS was active.
AT+UGGGA?	+UGZDA: 0,NULL OK	If storing of the last value of the $GGA string was not activated before, its value cannot be read.

Table 17: NMEA string reading

3.4 Sending UBX strings via AT commands

It is possible to send commands to the u-blox GNSS receiver in proprietary UBX format through the AT interface: UBX strings are encapsulated into AT+UGUBX command (for more details, see the command description in u-blox AT Commands Manual [1] or u-blox CDMA AT Commands Manual [20]).

The UBX message must be in hexadecimal format: spacing bytes is not mandatory although messages can include spaces to simplify copy/paste from u-center, e.g. AT+UGUBX="B5 62 06 01 08 00 01 06 00 01 00 00 00 00 17 DA" is equivalent to: AT+UGUBX="B562060108000106000100000000017DA".

☞ The total length of the command AT+UGUBX shall not exceed 108 bytes (including spaces inserted in the UBX string). If the message length is exceeded or if the command is wrong, an error result code is issued.

☞ Use of UBX CFG-PRT command is not recommended since the cellular module can lose communication with the GNSS receiver. In this case, even if the command is correctly executed, it is possible to receive an error indication due to the missing GNSS receiver answer.

☞ The cellular module automatically calculates the UBX checksum before sending the message to the GNSS receiver.

☞ It is recommended not to send ubx messages to reset the GNSS while it is in use. This will cause a misalignment between the configurations of the modem and the GNSS receiver. Furthermore it is recommended not to configure the GNSS power saving with the tx data ready active, because the GNSS receiver could send wrong reading requests to the modem.

When the GNSS receiver is turned off, the last UBX string is not sent, but saved in RAM, and will be passed to the GNSS receiver. This string should be used as configuration for "GNSS data ready" function. This message is only used if the GNSS receiver HW is u-blox 7 or above and the "GNSS data ready" function is enabled.

☞ On LEON-G100-06x / LEON-G200-06S and previous versions the command AT+UGUBX can be only used when the GNSS is used from the AT interface (power on by AT+UGPS=1,x); this means the external configuration for "GNSS data ready" function is not supported.

4 Aiding features

GNSS receivers alone cannot always provide instant position information because it is necessary to receive signals from at least four satellites to derive their precise orbital position data, called ephemeris. Under adverse signal conditions, data download from the satellites to the receiver can take minutes, hours or even fail altogether. Assisted GNSS (A-GNSS) boosts acquisition performance by providing data such as ephemeris, almanac, accurate time and satellite status to the GNSS receiver via mobile networks or previously stored information. Aiding data enables the receiver to compute a position within seconds, even under poor signal conditions. For timings scenarios, see the u-blox Receiver Description document related to the u-blox GNSS receiver [10] [11] [12] [13].

The basic command used to activate and deactivate the GNSS receiver from the cellular module is AT+UGPS. The first parameter allows switching on (value = 1) or switching off (value = 0).

At the GNSS receiver power-on through the AT+UGPS command the aiding mode and the GNSS system must be properly configured through the second and third parameter respectively of the same command. The GNSS aiding is a set of specific features developed by u-blox to enhance positioning performance, decreasing the TTFF and increasing the accuracy. For more details see the u-blox Receiver Description document corresponding to the related u-blox GNSS receiver [10] [11] [12] [13].

u-blox cellular modules support 4 different types of GNSS aiding:

- Local aiding
- AssistNow Offline
- AssistNow Online
- AssistNow Autonomous

The second parameter of AT+UGPS command allows configuration of one or more assistance modes (e.g. "4" for AssistNow Online), or "0" if no aiding mode is required.

Once the GNSS receiver is powered on by the AT+UGPS command, aiding mode and GNSS system may be changed on a runtime basis by issuing a new AT+UGPS command with different aiding and/or GNSS system parameters. If an AT+UGPS command is issued to an already powered on GNSS device with the same aiding mode and same GNSS system as the previously selected, an error result code is returned.

For more details see u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20], +UGPS AT command.

☞ On LEON-G100-05S / LEON-G200-05S and previous version, it is not possible to switch aiding mode while the GNSS receiver is active.

Each aiding mode is briefly described in the following sections. For additional information, see the u-blox Receiver Description document related to the u-blox GNSS receiver [10] [11] [12] [13]. Some common points:

- No aiding mode is enabled by default: when switching on the GNSS receiver, it is necessary to specify the desired aiding mode(s)
- The GNSS systems mode parameter is optional. If the connected GNSS receiver is a multi-GNSS receiver, then it is used to activate the required GNSS system, otherwise it is ignored. If the GNSS system mode is omitted for a multi-GNSS receiver, the default configuration GPS+SBAS system is activated. If a required GNSS system cannot be activated (because it is not supported) the GNSS system configuration saved in the receiver will be activated. For further details on the default GNSS system configuration for a multi-GNSS receiver see the u-blox GNSS Protocol Specification.
- The GNSS aiding modes can be combined to further increase performance, additional details are provided in the section 4.5
- Some assistance modes require a packet data connection to exchange information with u-blox servers

- When the GNSS receiver is switched on through the cellular module, the "OK" result code is returned on the serial port once the communication is established. If the GNSS does not respond within 5 s, an error result code is issued: in this case check the I^2C interface and the power supply pin connection
- Once the communication between cellular module and GNSS receiver is established on the I^2C interface, the cellular module tries to perform the requested GNSS system activation (for a multi-GNSS receiver) and aiding type. In case of aiding failure (e.g. no network coverage, no data connectivity, expired alp file etc.) the GNSS receiver operates without aiding

☞ The +UUGIND URC provides the aiding notification in the form +UUGIND: <aiding_mode>,<result>. The allowed aiding results are available in section 4.6. The feature is disabled by default and is enabled via the dedicated command AT+UGIND=1 (for more details see the u-blox AT Commands Manual [1] or u-blox CDMA AT Commands Manual [20]).

☞ For a multi-GNSS receiver the +UUGIND URC provides notification for the activated GNSS systems in the form +UUGIND: 0,<GNSS_system>. The feature is by default disabled and can be enabled via the dedicated command AT+UGIND=1 (for more details see the u-blox AT Commands Manual [1] or u-blox CDMA AT Commands Manual [20]).

The application should enable GNSS-related URCs. Once the application has activated GNSS-related URCs and started the GNSS with the required GNSS system and aiding mode, URCs should be monitored to verify successful completion. An example of AT command sequence is shown below:

Command	Response	Description
AT+UGRMC=1	OK	Activate storing of the last value of $RMC NMEA string.
AT+UGIND=1	OK	Activate the unsolicited aiding result.
AT+UGPS=1,1,67	OK	Start the GNSS with GPS+SBAS+GLONASS systems and local aiding.
	+UUGIND: 0,67	URC reporting GNSS system activated.
	+UUGIND: 1,0	URC reporting GNSS mode “Local Aiding” ("1") and “No error” ("0").
AT+UGRMC?	+UGRMC: 1,$GNRMC,,V,,,,,,,,,N*53 OK	Read the last stored value of the NMEA $RMC string.
AT+UGPS=0	OK	Stop the GNSS.

Table 18: GNSS aiding modes AT command sequence

4.1 Using GNSS without aiding support

Typically the cellular module activates the GNSS receiver without any aiding mode. This is equivalent to switching on the positioning chip/module as a stand-alone, sending commands and receiving data using the AT commands port of the cellular module. The GNSS system parameter can be optionally issued to select a specific GNSS system, otherwise GPS+SBAS system is by default selected. Table 19 shows a command sequence.

The result code to the AT+UGPS=1,x[,GNSS_system] command is "OK" if the GNSS receiver responds within 5 s, otherwise an error result code is issued. If the GNSS URC notification is enabled (via the dedicated AT+UGIND command) then the GNSS systems activated are reported by the +UUGIND: 0,<GNSS_system> URC.

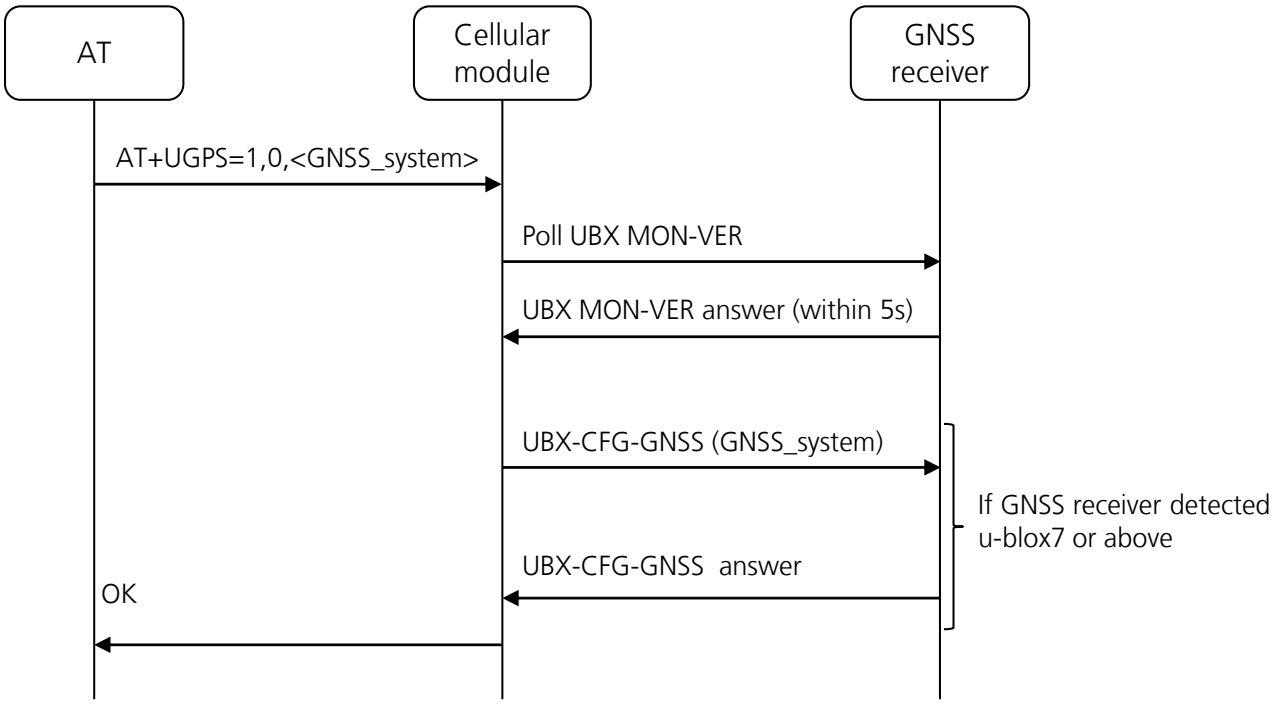

Figure 14: Interaction between the cellular module and GNSS receiver without aiding support

Command	Response	Description
`AT+UGRMC=1`	`OK`	Enable storing of the last value NMEA $RMC string.
`AT+UGPS=1,0,64`	`OK`	Start up the GNSS with GLONASS only system.
`AT+UGPS?`	`+UGPS: 1,0,64` `OK`	Read GNSS status. GNSS is powered on with GLONASS system and no active aiding.
		Allow the GNSS enough time to perform a fix.
`AT+UGRMC?`	`$GLRMC,151519.00,A,4542.84409,N,01344.46705,E,0.082,,280514,,,A*60` `OK`	Read the last stored value of the NMEA $RMC string.
`AT+UGPS=0`	`OK`	Stop the GNSS.

Table 19: AT command example without aiding support

4.2 Using GNSS with Local Aiding support

When the local aiding is enabled, the cellular module automatically saves GNSS-related data (position, time, ephemerides, almanac, health and ionosphere parameters) and information about the cell on which the cellular module is camped or registered, before the GNSS shut down. No data connection over the cellular network is required for local aiding. The local aiding is activated setting the second parameter of AT+UGPS to 1 (AT+UGPS=1,1,...). For more details see the u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20].

The aiding data is saved in RAM at GNSS power off, and it is copied to the cellular file system during cellular module power off. At each GNSS receiver startup, the location data is uploaded from the cellular module to the GNSS receiver.

☞ On LEON-G, SARA-G3, LISA-U1 series and LISA-U2 prior to 03S product versions the data is copied into file system after GNSS receiver power off.

Assistance data stored in the cellular module's file system is not visible or accessible to the user.

☞ On LEON-G100 / LEON-G200 and SARA-G340 / SARA G350 series the space in the file system is reserved.

☞ On LISA-U1, LISA-U2, LISA-C2 and SARA-U2 series the common file system space is used.

The local aiding algorithm uses the last known position and adjusts its accuracy according to the elapsed time. However, if the Cell ID has not changed, the last known position is used with an accuracy figure of a maximum cell coverage radius (35 km).

If no information regarding the previous position is available, a central position of the network is used (e.g. Rome for Italian networks) with the accuracy figure reflecting the uncertainty (e.g. 700 km in the case of Italy).

☞ Where the time zone information is available, LISA-C200 modules shall narrow down the estimate further by using a central position of the current time zone.

The aiding data can be manually saved at any time from the GNSS to the cellular module by sending the command AT+UGAOS=0. This operation is automatically performed when local aiding is enabled and the GNSS is switched off with AT+UGPS=0.

If the local aiding is enabled and the stored aiding data is obsolete (more than 2 hours), the GNSS receiver ignores it. Just before the GNSS is switched-off, the local aiding data is saved, overwriting the old data. This operation requires a few seconds.

If the GNSS has been switched on without local aiding enabled, when the GNSS is active and a fix has been calculated, the application can trigger aiding data saving by sending AT+UGAOS=0. Similarly, the usage of local aiding can also be forced after GNSS startup by sending AT+UGAOS=1. If GNSS-related URC responses are activated (by sending AT+UGIND=1), the command AT+UGAOS=1 triggers a response type +UUGIND=1,x, confirming that assistance data have been passed to the GNSS receiver.

If the GNSS receiver does not support multi-GNSS system, the GNSS-related aiding data saved on cellular file system are in the form of UBX-AID messages: AID-INI, AID-HUI, AID-ALM, AID-EPH.

If the GNSS receiver supports multi-GNSS system, the GNSS-related aiding data saved on cellular file system are in the form of UBX-MGA-INI (initial assistance data) and UBX-MGA-DBD messages (navigation database).

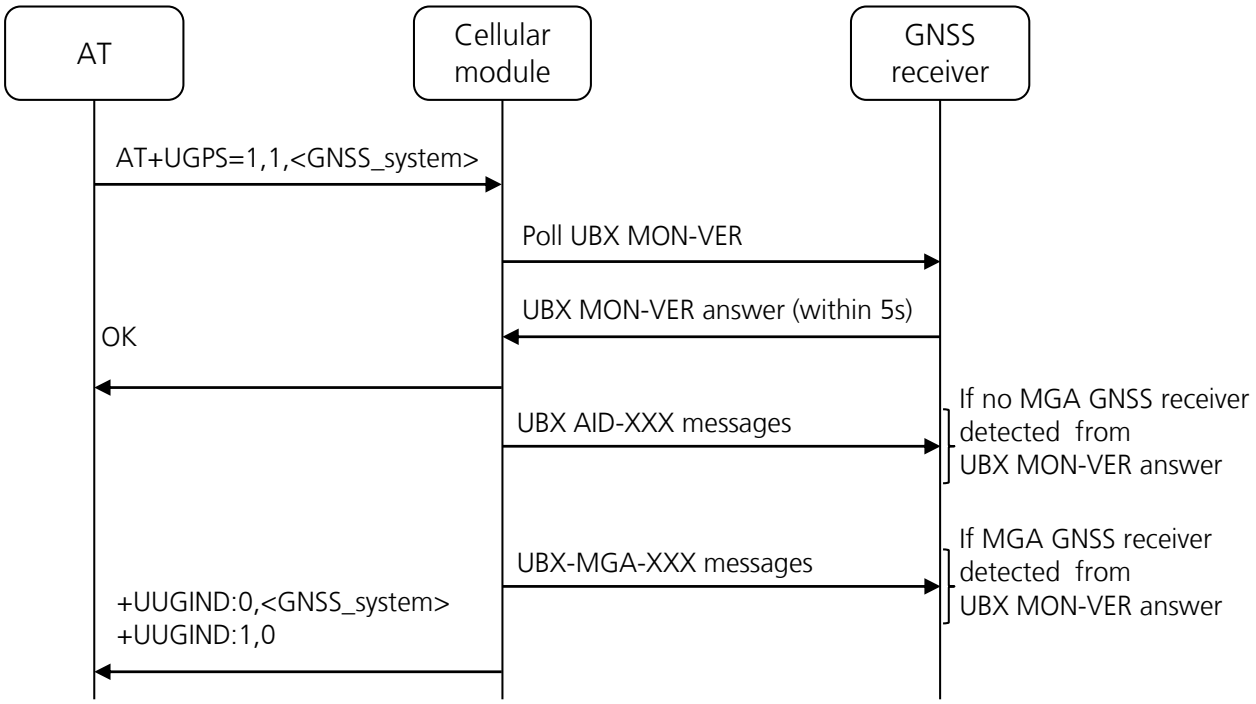

Figure 15: Interaction between the cellular module and GNSS receiver with local aiding support

If an error occurs, the +UUGIND URC will notify it; for more details on aiding error see the section 4.6.

☞ On LISA-C2 series modules the +COPS AT command is not required.

Command	Response	Description
AT+COPS?	+COPS: 0,0,"vodafone IT" OK	Check if the module is registered (GNSS local aiding will use cellular network information to reduce TTFF).
AT+UGRMC=1	OK	Activate storing of the last value of $RMC NMEA string.
AT+UGIND=1	OK	Activate unsolicited aiding result.
AT+UGPS=1,1,67	OK	Start up GNSS with GPS+SBAS+GLONASS systems and local aiding (it will download assistance data to GNSS if available in FS, otherwise it will use country code information for a rough localization).
	+UUGIND: 0,67	URC reporting GNSS system activated.
	+UUGIND: 1,0	URC reporting GNSS mode “Local Aiding” ("1") and “No error” ("0").
AT+UGRMC?	+UGRMC: 1,$GNRMC,083310.00 ,A,4542.84584,N,01344.4644 5,E,0.008,,290514,,,D*66 OK	Wait at least 15 minutes for ephemerides download.
AT+UGPS=0	OK	Stop the GNSS.

Table 20: Local Aiding AT command sequence

4.2.1 "GNSS RTC sharing" function

☞ See Table 3 to see which cellular modules support the "GNSS RTC sharing" function.

The "GNSS RTC sharing" function improves the positioning chip/module performance, decreasing the Time To First Fix (TTFF), and thus allowing position calculation in a shorter time and with higher accuracy. When the GPS local aiding is enabled, the cellular module automatically uploads data such as position, time, ephemeris, almanac, navigation database, health and ionosphere parameters from the GNSS receiver into its local memory, and restores this to the GNSS receiver at its next power-up.

Since with the local aiding the cellular module also provides a reference time to the GNSS receiver, the "GNSS RTC sharing" function can be enabled to improve the time accuracy for the GNSS receiver.

Through the "RTC calibration" process the cellular module can characterize its own RTC using the GNSS time, basically sending two pulses to the GNSS **EXTINT0** pin and reading the GNSS time reported by the GNSS (using the UBX message TIM-TM2) it is possible to calculate the RTC bias and drift.

Knowing the RTC characteristics (typically vary with time and temperature), it is possible to estimate with high precision the time elapsed between two GNSS power cycles.

The RTC calibration is performed at GNSS power off (or when AT+UGAOS=0 is triggered). At the subsequent GNSS power on, if RTC calibration was successful and RTC clock has not been changed, a new pulse is sent to the **EXTINT0** pin and in the UBX-AID-INI message (or UBX-MGA-INI-TIME_UTC message for a multi-GNSS receiver) the pulse time is provided.

To only enable the "GNSS RTC sharing" function the first parameter of AT+UGPRF command must be set to 32. For more details on "GNSS RTC sharing" enabling and AT+UGPRF command description, refer to u-blox AT commands manual [1]. If the RTC out pin of the cellular module and EXTINT0 of the GNSS are not connected, the RTC calibration procedure will fail and time pulse is not sent with the UBX message.

☞ The calibration procedure requires more than 7 s, so the GNSS power off sequence takes more time when the "GNSS RTC sharing" function is enabled. The whole procedure could take up to 15 s.

☞ If the RTC time is modified between the RTC calibration procedure and subsequent GNSS power on, a wrong time and accuracy is passed to the GNSS receiver and this could decrease GNSS performance; to avoid this, modify the RTC when the GNSS is on or do not use local aiding right after RTC modification.

4.3 AssistNow Aiding Service

The AssistNow feature provides aiding data downloads for the connected GNSS receiver from a specific u-blox server. The cellular module contacts the server using an existing packet data connection.

AssistNow Offline downloads the aiding data from a u-blox HTTP server and saves it in the cellular file system, so that it can be transferred to the GNSS receiver at the next GNSS device power-on.

AssistNow Online downloads real-time aiding data from a u-blox server and then directly transfers the data to the powered on GNSS device.

The latest release of the AssistNow service provides aiding data for multi-GNSS receivers and uses a centralized server, which the cellular module contacts. Currently it is possible to access the AssistNow service in two different ways:

- AssistNow server access: it uses +UGAOF configuration options for AssistNow Offline access (HTTP server) and +UGAOP configuration options for AssistNow Online access (UDP LES server). Use of this access is suggested only if the +UGSRV AT command is not supported
- Multi-GNSS Assistance (MGA) server access: it uses a unique HTTP server for gathering both Offline and/or Online assistance data. For MGA server access, configuration options from AT+UGSRV are used. Configuration options in +UGSRV command includes an authentication token as a means of authorizing

access to the u-blox server and for gathering anonymous statistics. For further details on how to obtain a valid token, refer to www.u-blox.com/services-form.html. Configuration options in +UGSRV include a primary and secondary server name. The primary server name is the name of the preferred server to be contacted. If the connection with the primary server fails, the secondary server name will be used instead. The MGA service is the preferred AssistNow service access for present and future GNSS receivers. Configuration options in +UGSRV are saved to non-volatile memory (NVM) of the module, so they are reloaded after a cellular power cycle.

The GNSS implementation in cellular module firmware includes both the AssistNow server access and the MGA AssistNow server access. If an authentication token is defined in +UGSRV configuration options, then the GNSS aiding data is downloaded from the MGA server, otherwise the GNSS aiding data is downloaded from the AssistNow servers (+UGAOF / +UGAOP).

If the connected GNSS receiver is a multi-GNSS receiver, then the assistance data can be downloaded only from MGA access; in this case if the authentication token is not defined, an error +UUGIND: <aid>,16 URC code is returned if AssistNow Offline/Online aiding is requested with the +UGPS command.

☞ LEON-G, LISA-U, LISA-C series and SARA-G3x0-00S / SARA-G350-00X product versions do not support the MGA service access.

4.3.1 Using GNSS with AssistNow Offline support

GNSS AssistNow Offline stores the GNSS almanac for the configured GNSS system within the cellular module's FS. If there is no almanac file saved in the FS, then the cellular module will try to download it from the dedicated server using an existing packet data connection.

☞ If the assistance data needs to be downloaded, the application must activate a data connection (e.g. using AT+UPSDA) to allow the cellular module to establish a connection to the server. LISA-C2 series modules are always connected.

The configuration of AssistNow Offline can be performed through these commands

- AT+UGAOF for u-blox 7 and previous versions
- AT+UGSRV for all the GNSS receivers

After the file is downloaded from the server, it is renamed with the date and time plus ".alp" extension (if the old server was accessed) or ".mga" extension (if the MGA server was accessed) and passed to the GNSS receiver.

☞ On LEON-G100 / LEON-G200 series the file name is composed by the number of minutes elapsed from 01/01/2004.

If there is more than one AssistNow Offline data file on the file system, all the files, except the newest one, will be automatically deleted.

If the almanac file is downloaded from the old AssistNow Offline u-blox server, the URL configured through the +UGAOF command determines the validity period of the Differential Almanac Correction data: on u-blox server the last characters of the filename indicate the validity of the almanac expressed in days. Table 21 lists the Differential Almanac Correction files available on the u-blox server and their approximate size:

File Name	Validity	Approximate Size
current_1d.alp	1 day	10 kB
current_2d.alp	2 days	20 kB
current_3d.alp	3 days	25 kB
current_5d.alp	5 days	40 kB
current_7d.alp	1 week	50 kB
current_10d.alp	10 days	70 kB
current_14d.alp	2 weeks	100 kB

Table 21: Differential Almanac Correction files information

If the AssistNow Offline data is downloaded from the u-blox MGA server, configuration options from AT+UGSRV are used. Offline aiding data is requested by means of a HTTP request containing also the authentication token to be verified by the server. If the connected GNSS receiver is a Single-GNSS, then the <days> option determines the validity period of the Differential Almanac Correction data; if the connected GNSS receiver is a multi-GNSS, then <period>,<resolution> and <GNSS_types> options determine the aiding data to be downloaded. For more details on +UGSRV command, see the u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20]. The approximate size of an AssistNow Offline aiding file for a multi-GNSS receiver is typically around 200 kB.

If the .alp (or .mga) file download from the server fails, the system will automatically retry the operation according to parameters specified through the AT+UGAOF command. In case of an error, the GNSS is started anyway but no aiding is performed. The "retry" parameters specified via AT+UGAOF are applied also for the MGA server access connection.

The external application processor controlling the module should verify the validity period (the detailed procedure is described below) and download new AssistNow Offline data when needed. This can be achieved by sending AT+UGAOS=2 or simply deleting the .alp (or .mga) file before starting the GNSS receiver by means of the AT+UDELFILE command.

It is also possible to manually store the AssistNow Offline data file on the FS with the AT+UDWNFILE command. For more details on AT commands description refer to u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20].

The application processor can also decide to download new AssistNow Offline data to increase performance, e.g. substitute a 14-day validity file with a new one with 1-day validity after 5 days.

☞ Time and the date within the cellular module can be set using the following AT commands: +CCLK, +CTZU and +UGMTR. Refer to u-blox commands manual [1] or u-blox CDMA AT Commands Manual [20] for the commands descriptions. LISA-C200 series modules automatically default to the time and date specified broadcast by the CDMA network.

☞ To automatically download a new file from the server, the following conditions need to be satisfied:

- Active packet data connection
- GNSS receiver on
- AssistNow Offline aiding enabled
- The AssistNow Offline aiding file is expired or nearing expiration (less than 10% of validity time left)

☞ On LEON-G100-05S / LEON-G200-05S and previous versions it is not possible to automatically download the file from the server.

The external application processor should perform the command sequence as follows:

1. Decide a validity period of n days and store the current date somewhere (it is also possible to use the renamed file in the FS to derive the assistance file validity).
2. (AssistNow server access): Use the AT+UGAOF command to select the file to download by setting the appropriate URL, i.e. "http://alp.u-blox.com/current_14d.alp" for two weeks or "http://alp.u-blox.com/current_1d.alp" for one day; OR

2. (MGA server access): Use the AT+UGSRV command to select the period and resolution of aiding data to download
3. Start the GNSS in AssistNow Offline mode (e.g. AT+UGPS=1,2,… for more details refer to u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20]).
4. Before each subsequent GNSS startup in AssistNow Offline mode check if the Assistance data file is still valid (current_date – download_date < validity period).
5. If the file is no longer valid, delete it from the FS using the command AT+UDELFILE.
6. Start the GNSS in AssistNow Offline mode (AT+UGPS=1,2….).

☞ On LISA-C200 series modules the +UPSD and +UPSDA AT commands are not required. The data connection shall automatically be set up.

Command	Response	Description
AT+UGAOF?	+UGAOF: "http://alp.u-blox.com/current_14d.alp",0,1,3 OK	Check the AssistNow Offline configuration (needed only if there is no almanac file in the FS). The validity of the assistance data is given by the file name (deprecated access)
AT+UGSRV?	+UGSRV: "cell-live1.services.u-blox.com","cell-live2.services.u-blox.com","12345678901234567890AB",14,4,1,65,0,15 OK	Check the AssistNow configuration for MGA access (needed only if there is no almanac file in the FS). The validity of the assistance data is given by <period> option. A valid authentication token must be supplied to correctly access the MGA server. If the token is not defined ("") and the connected GNSS receiver is a Single-GNSS, then the AssistNow server (+UGAOF) will be used on following AssistNow Offline request.
AT+UGIND=1	OK	Activate the unsolicited aiding result.
AT+UPSD=0,1,"web.omnitel.it"	OK	Set up the connection profile with the APN specified by the network operator.
AT+UPSDA=0,3	OK	Activate the GPRS connection (needed only if there is no valid almanac file in the FS).
AT+UGPS=1,2,67	OK	Start the GNSS with GPS+SBAS+GLONASS systems and AssistNow Offline aiding. If there is no valid almanac file on the FS, it will be downloaded from the specified server).
	+UUGIND: 0,67	URC reporting GNSS system activated.
	+UUGIND: 2,0	URC reporting GNSS mode "AssistNow Offline" ("2") and "No error" ("0").
AT+UGPS=0	OK	Stop the GNSS.

Table 22: AssistNow Offline AT command sequence

☞ The AT+UGAOS=2 command triggers the Offline aiding data file download when the GNSS receiver is switched on, but the new file will be used only when the GNSS receiver is restarted with AT+UGPS=1,2,….

☞ The longer the validity of the aiding file chosen, the larger the aiding file is. Furthermore, the size of the aiding file increases if both GPS and GLONASS aiding data are requested. If the FS is used for other applications, it is necessary to verify that there is enough space to store the assistance data. If space saving is an issue, it is recommended to use the aiding data with the shortest validity.

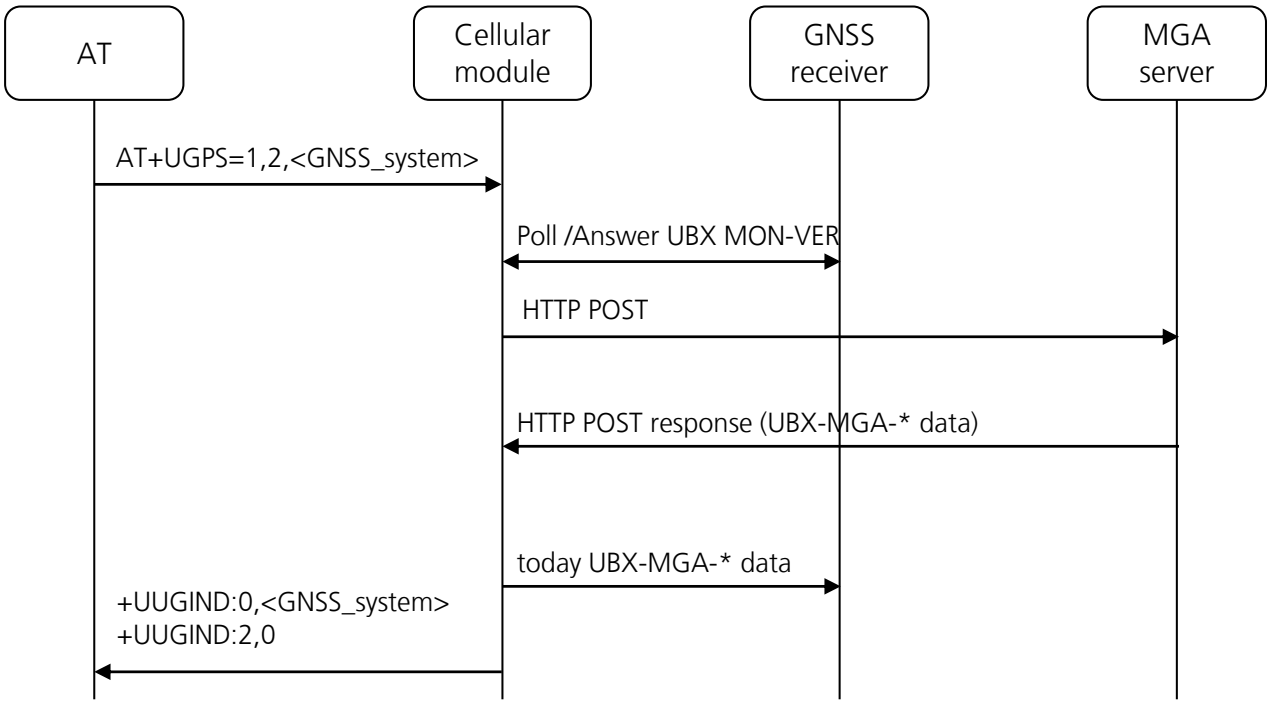

Figure 16: Interaction between the cellular module and GNSS receiver with AssistNow Offline support

☞ The cellular module does not perform checks on the almanac file: it just notifies the GNSS that an alp/mga file is available on the cellular module file system. If the file is corrupted or out of date, the GNSS determines if it will not use it, and in this case, no error notification is provided.

4.3.2 Using GNSS with AssistNow Online support

AssistNow Online is the assistance mode ensuring the fastest TTFF. Assistance data is downloaded from the cellular module and then passed to the GNSS receiver.

☞ An active packet data connection is required to exchange data between the cellular module and u-blox dedicated server.

At GNSS startup, a data connection is created either to the u-blox AssistNow Online Server or to a configurable proxy server: for AssistNow server assistance, a UDP socket is created when the cell information is available; for MGA server assistance, a HTTP session is created instead. The cellular module will pass the active cell information to the server and the server will return the aiding data only for those satellites visible by the GNSS receiver at a given time.

☞ The address eval1-les.services.u-blox.com is the AssistNow Online Server, which also supports CellLocate® requests.

☞ The addresses cell-live1.services.u-blox.com and cell-live2.services.u-blox.com are respectively the primary and secondary servers for the preferred MGA Online Server, which also supports CellLocate® requests.

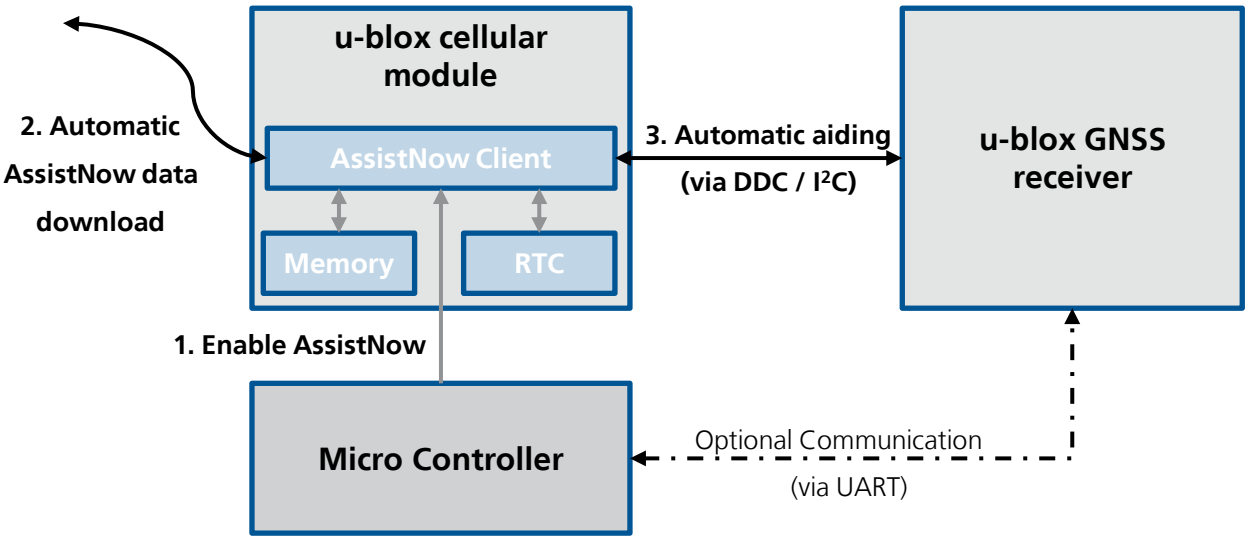

Figure 17: AssistNow Online flow

If no data socket is available, then the GNSS receiver will start without aiding and the URC will provide an error result code.

If there is no response from AssistNow Online, the cellular module will make three repeated attempts (at intervals of 10 s, 30 s and 60 s respectively).

The authentication for the u-blox AssistNow Online Server eval1-les.services.u-blox.com is performed at the beginning of each access to the u-blox AssistNow server by sending the information listed below:

- Exclusive OR of IMSI and IMEI
- Home network code
- Information about the active and neighboring cells used by the cellular module
- Latency

The authentication for the u-blox MGA Server cell-live1.services.u-blox.com is performed by the verification of the authentication token when sending the HTTP request.

After a successful access and download of assistance data, when a fix is available the cellular module provides the position information to the server for quality monitoring purposes.

If the server contacted is eval1-les.services.u-blox.com, the following information is sent:

- Exclusive OR of IMSI and IMEI
- Calculated position after aiding
- Position accuracy
- Number of SVs used
- TTFF

If the server contacted is cell-live1.services.u-blox.com, the position information is submitted by means of a HTTP POST.

The data payload sent from the module to the server during the AssistNow Online procedure is about 54 bytes during the authentication phase and about 35 bytes during the confirmation phase. If the MGA server is used as assistance server the amount data for querying information is about 200 bytes. Amount of aiding data downloaded from the server is variable.

☞ On LISA-C200 series modules the +UPSDA AT command is not required.

Command	Response	Description
AT+UGAOP?	+UGAOP: "eval1-les.services.u-blox.com",46434,1000,0 OK	Check if AssistNow Online is configured.
AT+UGSRV?	+UGSRV: "cell-live1.services.u-blox.com","cell-live2.services.u-blox.com","12345678901234567890AB",14,4,1,65,0,15 OK	Check the AssistNow configuration for MGA access. A valid authentication token must be supplied to correctly access the MGA server. If the token is not defined ("") and connected GNSS receiver is a Single-GNSS, then the AssistNow server (+UGAOP) will be used on following AssistNow Online request
AT+UPSDA=0,3	OK	Activate the GPRS connection using the +UPSDA AT command.
AT+UGPS=1,4,67	OK	Start up the GNSS with GPS+SBAS+GLONASS systems and AssistNow Online aiding (it will send network cell information to the server and receives aiding data for the GNSS).
	+UUGIND: 0,67	URC reporting GNSS system activated.
	+UUGIND: 4,0	URC reporting GNSS mode "AssistNow Online" ("4") and "No error" ("0").
AT+UGPS=0	OK	Stop the GNSS.

Table 23: AssistNow Online AT command sequence

The AT+UGIND=1 command enables the URCs. A URC is sent when the AssistNow Online procedure is complete, so the indication is provided after the GNSS fix and the notification to the server. If an error is encountered during the AssistNow procedure, the corresponding URC will report it. Refer to the AT+UGIND command description within the u-blox AT Commands Manual [1] or u-blox CDMA AT Commands Manual [20].

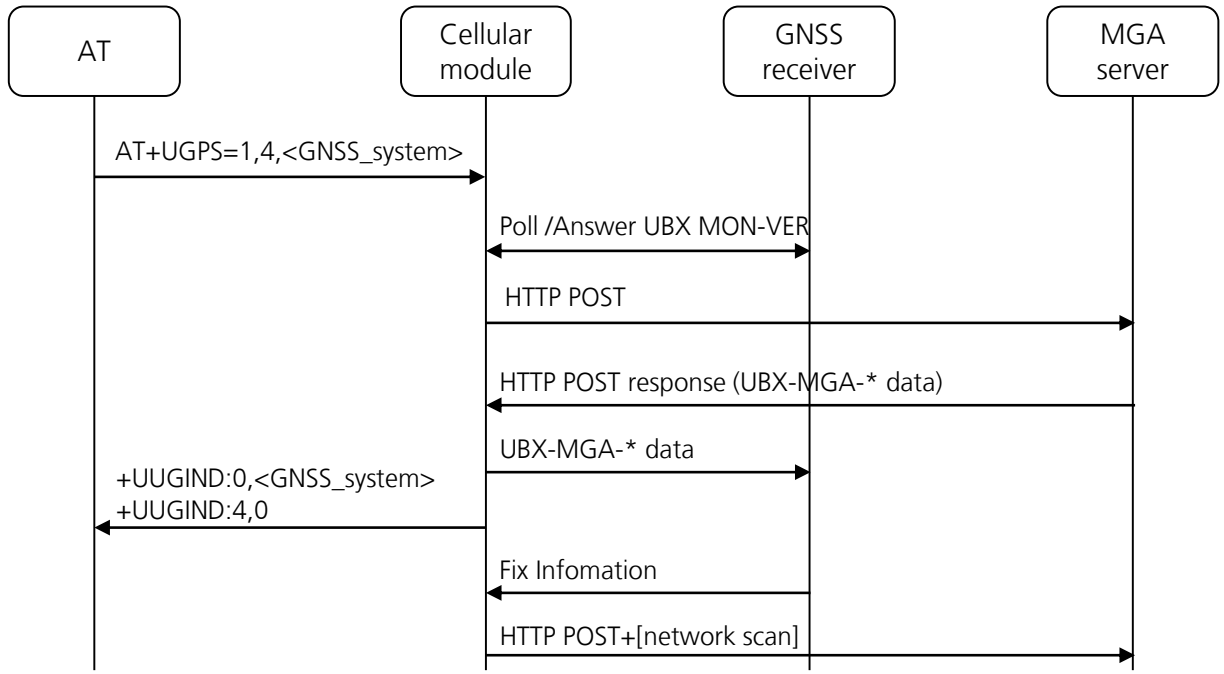

Figure 18: Interaction between the cellular module and GNSS receiver with AssistNow Online support

4.3.2.1 Latency

The latency parameter is the expected time for data to arrive at the GNSS receiver from the server. If there is a significant latency between the instant when the cellular module receives AssistNow data and when it is received by the GNSS receiver, this should also be added to the latency parameter.

☞ On LEON-G series, if the latency varies excessively from the predicted value, then the cellular module will send a new aiding request with an adjusted latency. The server sets the time accuracy field within the AssistNow data to half of the reported latency. For example, with a latency of 500 ms, the AssistNow server adjusts the time in the data by 500 ms and sets the accuracy value in the AssistNow UBX data to 250 ms. With this value, the GNSS receiver assumes that the given time is accurate to +/-250 ms. Thus, in this example, if the measured latency between GSMREQ and AssistNow data received by the cellular module is between 500 ms and 1500 ms no new request is required.

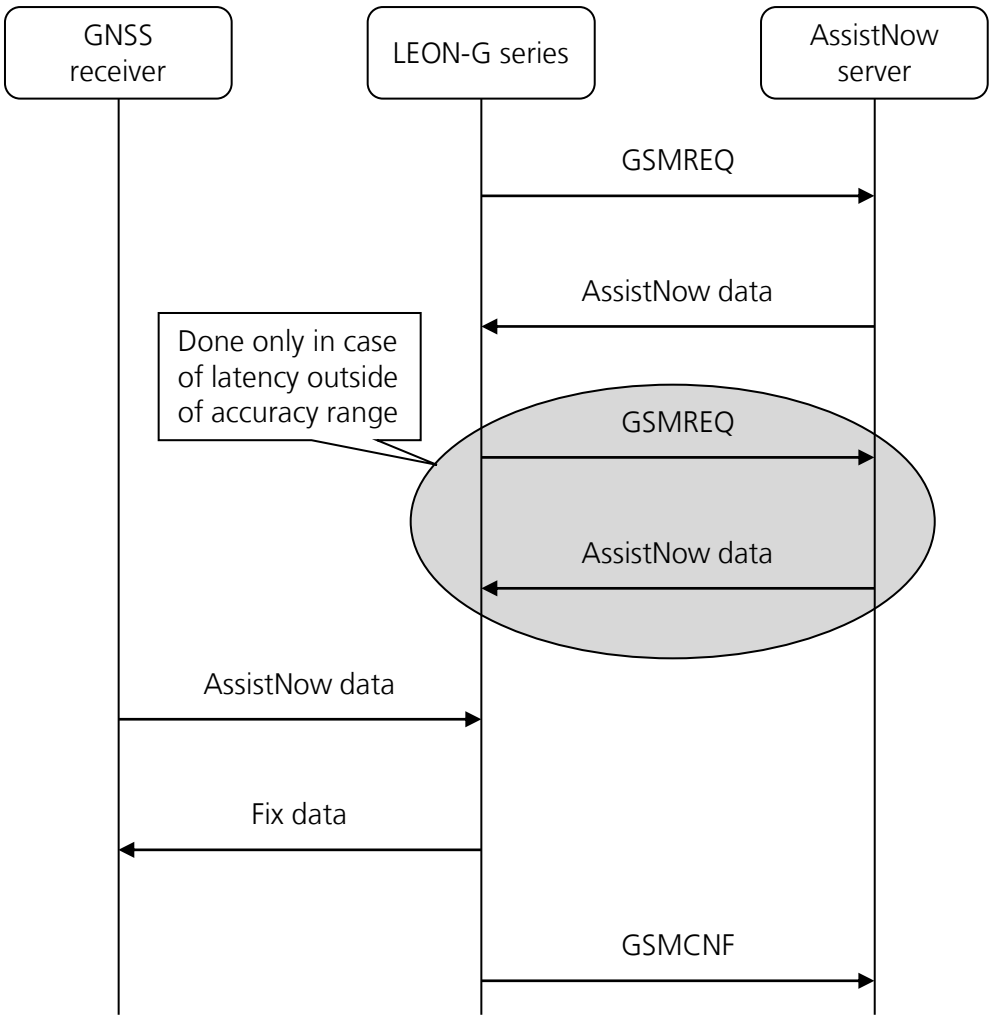

Figure 19: AssistNow message flow between the cellular module and the server

4.4 Using GNSS with AssistNow Autonomous Support

☞ Refer to section A.3 for more details about the availability of AssistNow Autonomous on u-blox GNSS receiver.

☞ Refer to section 1.3 for more details about the availability of AssistNow Autonomous on u-blox cellular modules.

The AssistNow Autonomous feature provides functionality similar to AssistNow without the need for a host and a connection. Based on the known ephemeris, the GNSS receiver can autonomously generate an accurate satellite orbit representation that is usable for navigation much longer than the underlying broadcast ephemeris was intended for.

The AssistNow Autonomous data is automatically and autonomously generated from downloaded (or assisted) broadcast ephemerides. Data for the full constellation (32 satellites) is stored on the host file system.

AssistNow Autonomous feature may be not implemented for a specific GNSS system in a multi-GNSS receiver. If AssistNow activation fails for any reason, an error code is returned.

While AssistNow Offline data is available, the AssistNow Autonomous subsystem will not produce any data and orbits because it would be redundant information.

As with Local Aiding, data related to AssistNow Autonomous are saved within the cellular module FS but the file is not accessible or visible to the user.

For multi-GNSS receiver Autonomous, data is stored in the navigation database file, so the activation of AssistNow Autonomous automatically activates local aiding also.

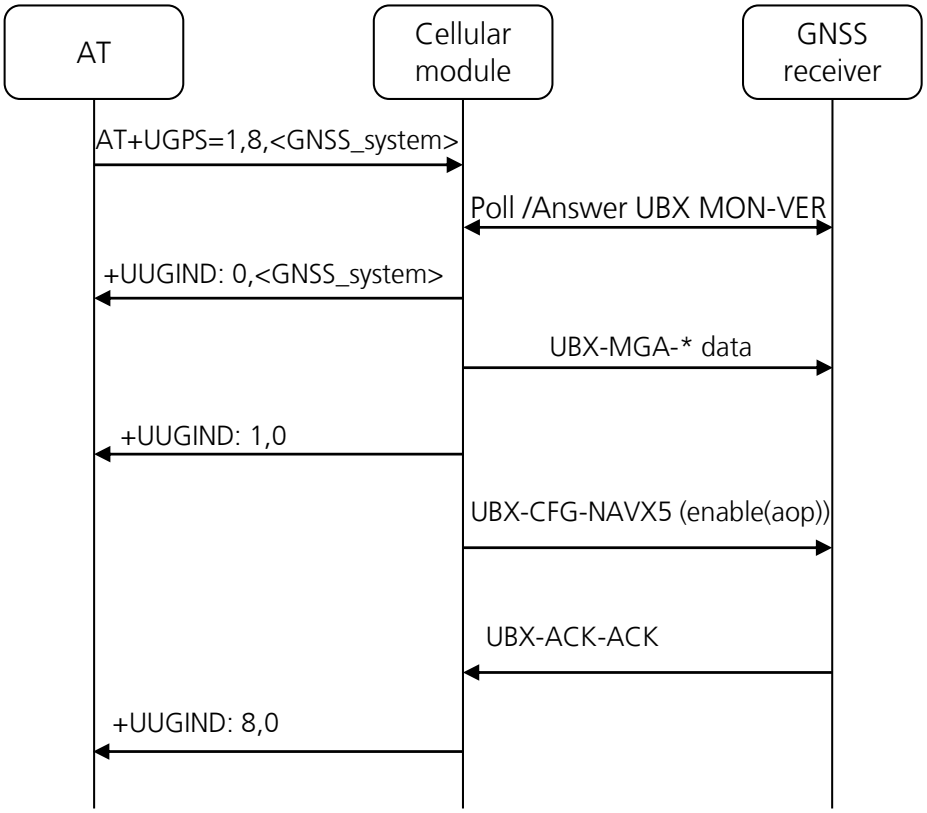

Figure 20: Typical interaction between the cellular module and multi-GNSS receiver with AssistNow Autonomous support

The +UUGIND URC is reported for each error/result.

Command	Response	Description
AT+UGRMC=1	OK	Activate storing of the last value of $RMC NMEA string.
AT+UGIND=1	OK	Activate the unsolicited aiding result.
AT+UGPS=1,8,67	OK	Start up GNSS receiver with GPS+SBAS+GLONASS systems and Autonomous aiding (it downloads data to GNSS receiver if available in the FS; otherwise it enables the AssistNow Autonomous in the GNSS receiver).
	+UUGIND: 0,67	URC reporting GNSS system activated.
	+UUGIND: 1,0	URC reporting GNSS mode "Local Aiding" ("1") and "No error" ("0"). Data have been passed to the GNSS.
	+UUGIND: 8,0	URC reporting GNSS mode "AssistNow Autonomous" ("8") and "No error" ("0"). AssistNow Autonomous has been activated.
AT+UGRMC?	+UGRMC: 1,$GNRMC,135612.00,A,4542.84609,N,01344.46417,E,0.004,,290514,,,A*65 OK	Read the last stored value of the NMEA $RMC string.
AT+UGPS=0		Stop the GNSS. Module automatically creates a file hidden to the user: ubx_aid_aop.dat.
	+UUGIND: 8,0	URC reporting GNSS mode "AssistNow Autonomous" ("8") and "No error" ("0"). AssistNow Autonomous has been deactivated
	+UUGIND: 1,0	URC reporting GNSS mode "Local Aiding" ("1") and "No error" ("0").
	OK	Answer to the AT+UGPS=0 command.

Table 24: AssistNow Autonomous AT command sequence

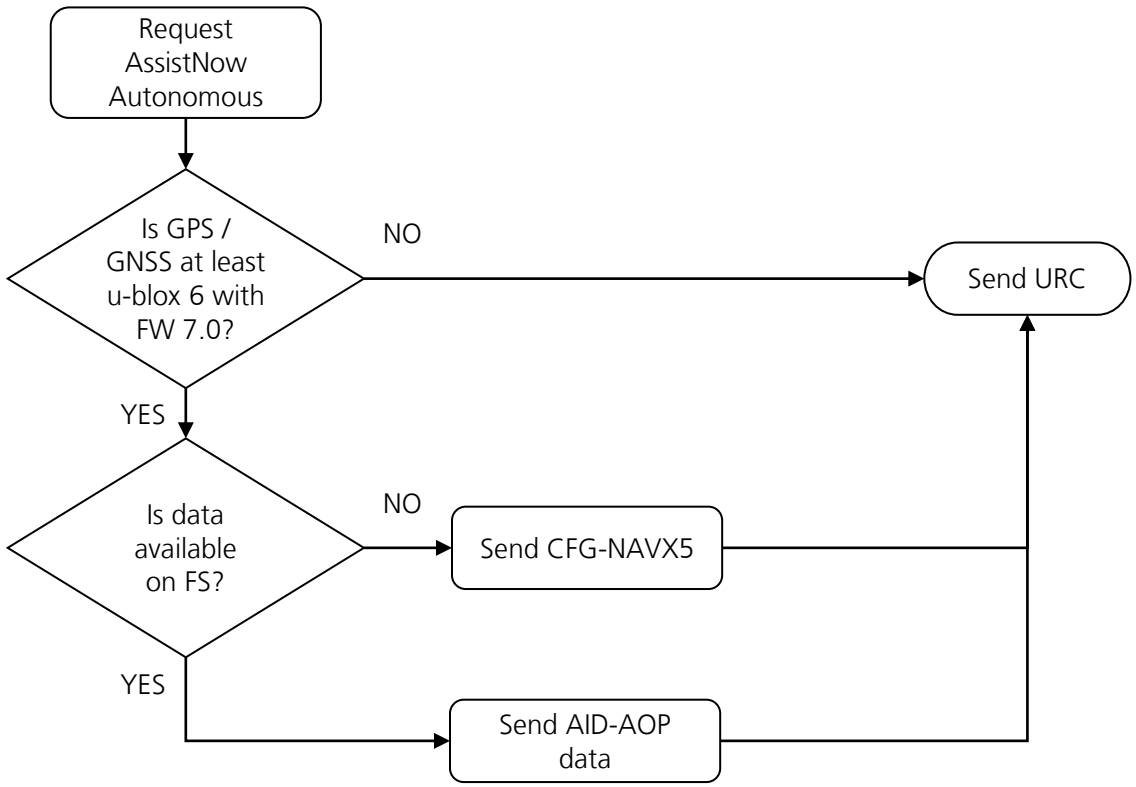

Figure 21: Detailed AssistNow Autonomous start sequence on a single-GNSS receiver

4.5 Using GNSS with combined aiding modes

The GNSS aiding modes previously described can be enabled at the same time when the GNSS receiver is switched on.

To enable more than one assistance mode, simply switch on the GNSS with the command AT+UGPS=1,x,y passing as second parameter the algebraic sum of the codes of each assistance mode desired. For example, to activate Local Aiding (normally activated with AT+UGPS=1,1) and AssistNow Autonomous (AT+UGPS=1,8), simply send AT+UGPS=1,9.

If the +UUGIND URCs are enabled, there will be an unsolicited text response for each mode activated.

Command	Response	Description
AT+UGIND=1	OK	Activate the unsolicited aiding result.
AT+UGPS=1,9,67	OK	Activate GNSS with GPS+SBAS+GLONASS systems and AssistNow Autonomous (AT+UGPS=1,8) and Local aiding (AT+UGPS=1,1).
	+UUGIND: 0,67	URC reporting GNSS system activated.
	+UUGIND: 1,0	
	+UUGIND: 8,0	
AT+UGPS=0		Stop the GNSS. The module automatically creates files hidden to the user.
	+UUGIND: 1,0	Local aiding data saved on the FS.
	+UUGIND: 8,0	AssistNow Autonomous deactivated.
	OK	Answer to the AT+UGPS=0 command.

Table 25: Combined aiding modes AT command sequence

4.6 Aiding result codes

The +UUGIND URC provides the aiding result; Table 26 lists the allowed aiding results:

Aiding result	Description
0	No error, this message is sent when the aiding procedure is complete. With AssistNow Online the procedure is complete when the position information is sent back to the server. Local aiding and AssistNow Autonomous also perform aiding action during power off sequence, therefore they also provide URC in this phase
1	The URL provided with +UGAOF command for AssistNow Offline is not valid
2	The HTTP GET request for AssistNow Offline file has failed
3	UDP socket creation for AssistNow Online failed
4	During AssistNow Online procedure the UDP socket closure returned an error
5	It was not possible to send AssistNow Online information to the server
6	There was an error while receiving for AssistNow Online data from the server
7	It was not possible to connect to the AssistNow Online server or to resolve its DNS
8	Error writing data in the file system
9	Generic error
10	No answer from GNSS after a data request (for local aiding and AssistNow Autonomous)
11	Data collection already in progress (for local aiding)
12	GNSS activation of AssistNow Autonomous failed
13	RTC calibration procedure has not been completed (for local aiding)
14	Feature not supported by GNSS receiver (for AssistNow Autonomous)
15	Feature partially supported (for AssistNow Autonomous)
16	Authentication token missing (required for MGA assistance server connection)

Table 26: GNSS aiding feature compatibility matrix

5 GNSS input/output

The AT+UGPRF command configures the communication and the data redirection between the GNSS receiver and the cellular module. Apart from enabling "GNSS Data Ready" and "GNSS RTC sharing", GNSS data can be redirected from the DDC interface in the following modes, which can be combined:

- to a USB channel
- to a multiplexer virtual channel
- to a file in File System
- over the air (OTA)

☞ On LEON-G, LISA-C and SARA-G3 modules the GNSS data cannot be redirected to a USB channel.

The configuration can be only done when the GNSS receiver is off. For more details, see the u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20], AT+UGPRF command.

☞ On LISA-C200 series modules, the +UPSDA AT command is not required.

Command	Response	Description
`AT+UGPRF=4`	`OK`	Enable GNSS I/O configuration on the FS.
`AT+UPSDA=0,3`	`OK`	Activate the GPRS connection using the +UPSDA command.
`AT+UGPS=1,0,3`	`OK`	Start up the GNSS receiver with GPS+SBAS system and without aiding.
`AT+UGAOS=4`	`OK`	Force AssistNow Online and wait some minutes.
`AT+UGPS=0`	`OK`	Stop the GNSS receiver.
`AT+ULSTFILE=`	`+ULSTFILE: "GPS_20040101_001"` `OK`	Check if trace file has been generated.
`AT+UGPRF=6`	`OK`	Start the multiplexer driver on host and then enable GNSS communication on multiplexer and trace on the FS.
`AT+UGPS=1,0,3`	`OK`	Start up the GNSS receiver with GPS+SBAS system and without aiding, the GNSS output is visible on GNSS tunneling channel.
`AT+UGAOS=0`	`OK`	Force local aiding data download.
`AT+UGPS=0`	`OK`	Stop the GNSS receiver.

`AT+ULSTFILE=`	`+ULSTFILE: "GPS_20040101_002"`
	`,"GPS_20040101_001"`
	`OK`
		Check if trace file has been generated.

Table 27: GNSS data redirection AT command sequence

The multiplexer and the USB are input/output channels, while the FS and network are only output channels.

5.1 USB I/O

The USB 4 is reserved for GNSS tunneling; this means that it is possible to directly communicate with the GNSS using the UBX protocol.

☞ The tunneling through USB interface is not available on LEON-G, LISA-C and SARA-G3 series.

☞ The tunneling through USB interface is mutually exclusive with the multiplexer channel.

☞ It is recommended not to send ubx messages to reset the GNSS while it is in use. This will cause a misalignment between the configurations of the modem and the GNSS receiver. Furthermore it is recommended to not configure the GNSS power saving with the tx data ready active, because the GNSS receiver could send wrong reading requests to the cellular module

5.2 Multiplexer I/O

The cellular module FW supports the 3GPP TS 27.010 multiplexer protocol (for more details, refer to 3GPP TS 27.010 specifications [3]) to emulate several virtual connection channels on a single physical interface to concurrently access the module (e.g. it is possible to read a phonebook contact while receiving GNSS data).

☞ For more details on multiplexer implementation on cellular module, refer to Multiplexer Implementation Application Note [2].

☞ The 6th virtual channel has been dedicated to GNSS tunnel data to the host.

☞ On SARA-G340 / SARA-G350 series, the GNSS data flow on the multiplexer channel is only in output toward the cellular module; the input to the GNSS receiver is not supported.

u-blox cellular modules provide the following virtual channels

- Channel 0: control channel
- Channel 1 – 5: AT commands / data connection
- Channel 6: GNSS tunneling (if available)
- Channel 7: SAP (SIM Access Profile) (if available)

5.3 FS output

A single log file saved on the FS is limited to 500 kB, while the total FS usage for log files is limited to 750 kB. When the FS nears its maximum capacity, the file is closed and no other log file is created and no indication is sent. However the string "--file truncated--" is appended to the end of the log file. If the positioning chip/module is restarted, a new file will be created if the total FS usage is not exceeded.

GNSS log files are visible within the user space and their name has the following format: GPS_YYYYMMDDHHMM. YYYYMMDDHHMM is the date and time obtained from the system. A generated log file overwrites any existing file with the same filename. This may happen if the system time has been changed or the GNSS log is started twice in the same minute.

GNSS data is stored as it is received, no data compression is performed.

☞ On LEON-G100 / LEON-G200 series, the log file names have the following format: GPS_YYYYMMDD_nnn (YYYYMMDD is the date while nnn is an incremental index).

☞ On LEON-G100 / LEON-G200 series, there is no limit on the total FS usage for log files.

☞ On LEON-G100 / LEON-G200 series, a truncated log files is not ended with "--file truncated--" string.

5.4 OTA output

The GNSS output can be redirected to a server via a data connection, this communication is mono-directional, so it is not possible to send UBX commands to the positioning chip/module receiver. The TCP protocol is used to transport data.

☞ Except for LISA-C2 series modules, before starting this transfer mode, a packet data connection must be properly set up.

6 Hybrid positioning and CellLocate®

☞ Hybrid Location and CellLocate® features are not available with LEON-Gx00-05S and previous versions and LISA-C200.

Although GNSS is a widespread technology, the reliance on the visibility of extremely weak GNSS satellite signals means positioning is not always possible, particularly in shielded environments such as indoors and enclosed park houses, or when a GNSS jamming signal is present. This situation can be improved by augmenting GNSS receiver data with mobile network cell information to provide a level of redundancy that can benefit numerous applications.

Hybrid location provides a set of features, allowing the user to query the device position using a single AT command (AT+ULOC) which triggers the position calculation based on the GNSS receiver and/or the position estimated from the visible cells (CellLocate®). The MGA server accessed for the position estimation is configured by AT+UGSRV command for multi-GNSS receiver.

Hybrid positioning is designed to provide a single position estimate or multiple position estimates.

Hybrid positioning may be configured to provide a single position estimate, on request, using the best of all the available information. Example applications might be

1. Logistics operations, by managers wishing to determine where assets are, even though they may temporarily be inside in a depot. In this application hybrid positioning is activated on request, and if the device does happen to be inside a building the accuracy provided by CellLocate® when indoors is sufficient to establish at which depot the device is located
2. Alert applications, where the users want to report their location, even if they go indoors. Best performance is achieved in such applications by periodic hybrid position requests by the user's device to maintain a current estimate of the environment, and so give an excellent ability to respond with an accurate location in the event of an alert
3. Localized operations, where the position awareness is desired over a small locality or site, such as a hospital or village. In this type of operation, the locality to be covered can be surveyed prior to usage, by walking around the region doing periodic hybrid position requests, and thereby gathering detailed information on the cellular environment by CellLocate® for use in the application

Hybrid positioning can also be configured to provide multiple position estimates: one solution from the GNSS receiver, if available, plus N solutions from CellLocate®. These may be useful in locations where:

- The visibility of the GNSS satellite is severely disturbed/attenuated and the accuracy of the GNSS solution would be highly degraded
- The area on interest is not densely populated in the CellLocate® database and, as a result, there are some solutions that may be equivalently good solutions.

If the customer's equipment has independent sensors (accelerometers, gyroscopes, magnetometers…) it may help in selecting between otherwise equivalent solutions.

This may help in locations, like near crossroads, where the knowledge of the direction (and speed) of motion may discriminate between two or more possibilities.

6.1 Positioning sensors

The following positioning sensors are supported:

- **GNSS receiver sensor**: the positioning chip or module is connected to the cellular module as described in previous sections and is configured by AT+ULOCGNSS command (the configuration includes the set of GNSS aiding modes and, if the connected receiver is multi-GNSS, the GNSS systems allowed to optimize the GNSS position calculation process).
- **Cellular sensor**: CellLocate® provides an estimated location based on visible network cell information reported by the cellular module and is configured by AT+ULOCCELL command. When CellLocate® is activated, a data connection to the CellLocate® server is established and the network cell information is passed to the server which provides an estimation of the device position based on the cell information. When using CellLocate®, the position accuracy is not predictable and is determined by the availability in the database of previous observations within the same area. CellLocate® does not require itself a GNSS receiver to be present or active, however the performance of the hybrid positioning is much better if GNSS is present.
- **Autonomous sensor**: the last known position (if available), with an accuracy that is degraded according to the elapsed time since then

Once the sensors are configured and a position request is triggered, the sensors are fully controlled by the cellular module. The cellular module automatically switches the sensors on, optimizes the power consumption, drives the position estimate methods and aiding/GNSS modes, and outputs the estimated position together with its uncertainty.

Figure 22 and Figure 23 show the sequence of the exchanged messages between involved elements when Hybrid positioning or stand-alone CellLocate® methods are used.

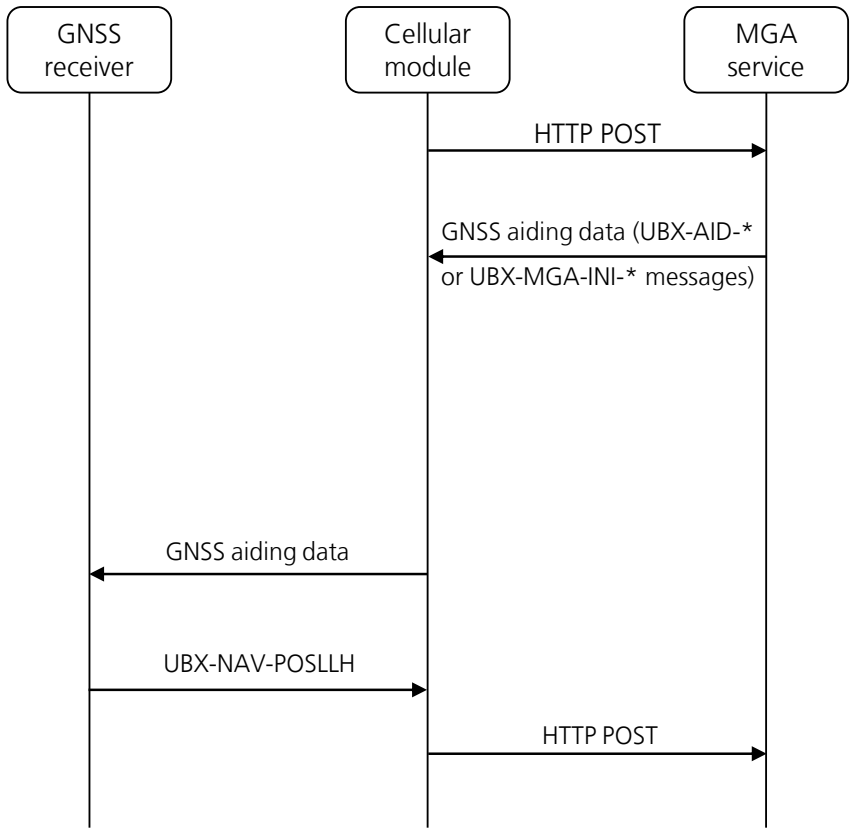

Figure 22: Hybrid positioning message sequence

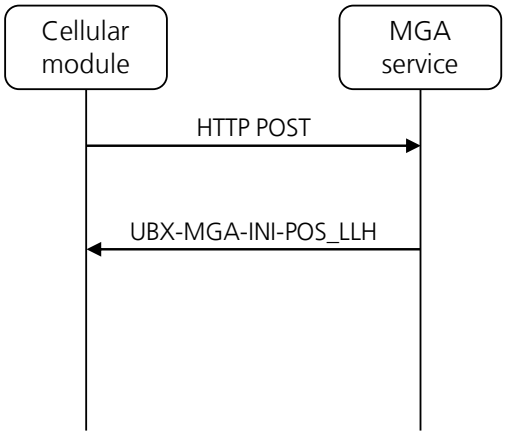

Figure 23: Stand-alone CellLocate® message sequence

☞ Stand-alone CellLocate® does not require a GNSS receiver and therefore is suitable for applications which do not require high positioning accuracy but where current consumption, compactness and cost reduction must be reduced to a bare minimum. Being cellular localization based on the cell(s) seen by the cellular module, the position estimation cannot be derived if the reported cell information is not available in the database.

☞ If the CellLocate® server, for whatever reason, cannot be reached during the +ULOC command execution, then the position will be calculated only using the GNSS sensor. The detailed response allows identification of the sensor that produced the position estimate.

The solution returned by CellLocate® is very much dependent on how well the database is populated in the specific area of interest. If only sparse observations are present, the accuracy of the solution and the estimated uncertainty will be quite large. Using +ULOC AT command in hybrid mode automatically submit new records to the database. In this way a device, with a GNSS receiver and a cellular module, will experience an improvement in the CellLocate® performance as time goes by since it contributes to the coverage of the area of interest.

The arrangement of mobile network cells does not remain static (e.g. new cells are continuously added or existing cells are reconfigured by the network operators). For this reason, when a Hybrid positioning method has been triggered and the GNSS receiver calculates the position, a database self-learning mechanism has been implemented so that these positions are sent to the server to update the database and maintain its accuracy.

6.2 Basic functionality

The two hybrid positioning sensors (GNSS and CellLocate®) are configured using AT commands (sensor configurations are explained later). When the +ULOC AT command triggers the sensor, the cellular module drives the position calculation process and provides the position estimate based on the sensor combination that best fulfills the user requirements previously configured.

☞ Hybrid positioning and communication with the GNSS receiver through the cellular module (see section 5) features are mutually exclusive and the activation of one of them requires the previous deactivation of the other one via AT+UGPS command.

The hybrid positioning function performed by the AT+ULOC command is controlled to meet the requirements of the particular application by the key parameters:

- the desired target accuracy
- the timeout during which a position must be returned
- single or multiple hypotheses flag (with the maximum number of hypotheses required)

When the timeout has expired or the required position accuracy is satisfied, a URC provides the position together with its uncertainty.

Figure 24 shows the general flow of the hybrid positioning function producing a position estimate.

To avoid unnecessary activation of the sensors, an initial check is carried out, and when hybrid positioning is used and before starting up the allowed sensors (GNSS and/or cellular), the cellular module immediately calculates a position estimate. This takes into account:

- the solution from the Autonomous sensor: the last known position (if available), with an accuracy that is degraded according to the elapsed time since then: it is assumed a speed equal to 120 km/h to degrade the position respect to time
- information provided by the serving cell, such as the country code

If the uncertainty of this estimate is already better than the target accuracy, then this position is output without starting up the allowed sensors.

If the uncertainty is poorer than the target one (or if no last known position is available), the cellular module powers up the allowed sensors and drives the position calculation process to output the position based on the sensors' combination, which better fulfills the +ULOC configuration.

As explained in the following sections, sensors (GNSS/CellLocate®/AS) are started up and operated as permitted by and in accordance with the predefined sensor configurations. The configuration settings may, for example, enable or disable the use of the CellLocate® service. Refer to the u-blox AT command manual [1] for the complete list of configuration supported by +ULOC command.

The GNSS receiver uses the sensors to repeatedly attempt to produce and refine a position fix, and may also use assistance information and position estimate from the CellLocate® service.

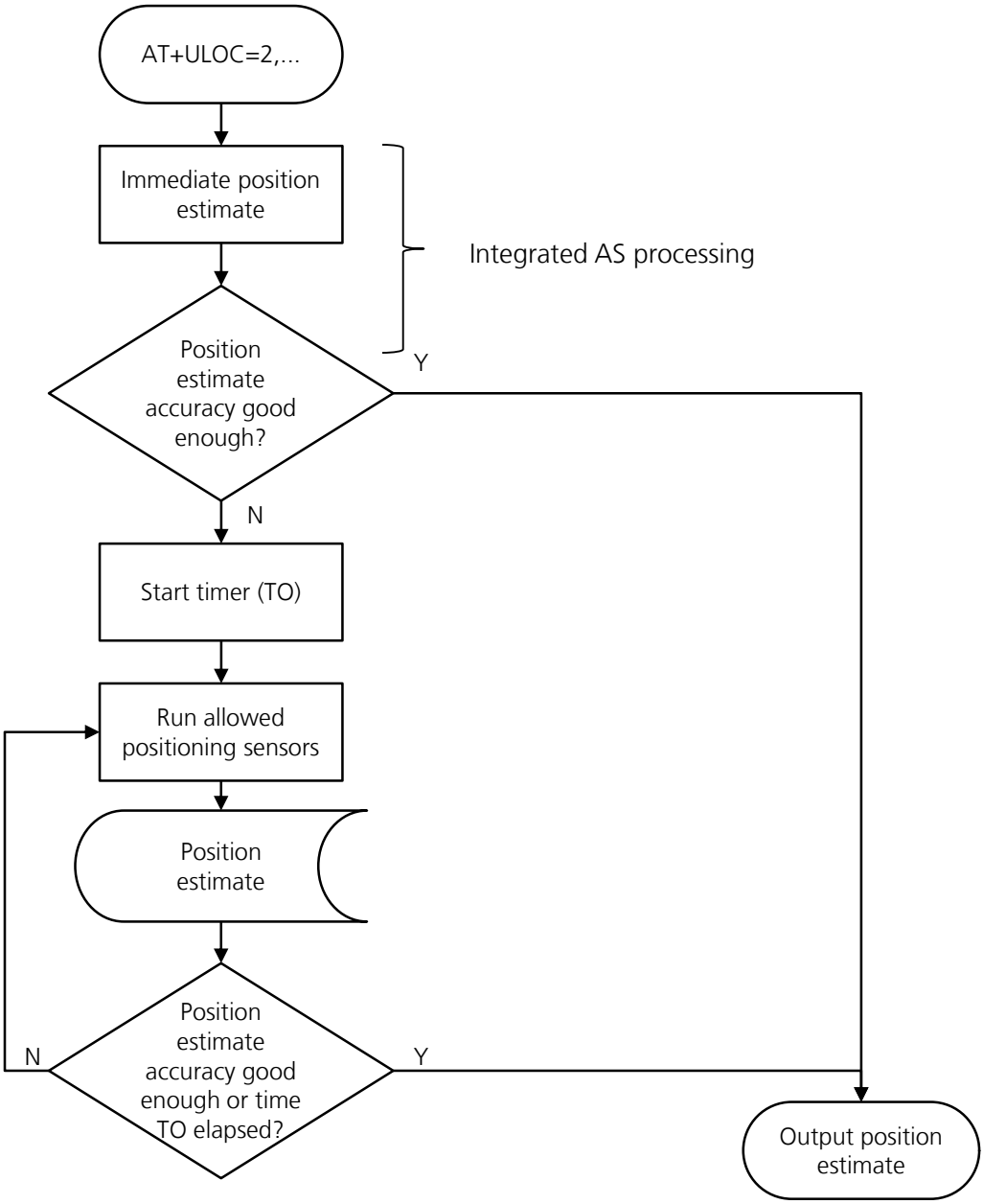

Figure 24: Hybrid positioning flow diagram

In due course, the Hybrid positioning feature either

- produces a position fix with an uncertainty figure that is at least as good as that requested
- experiences a timeout – in which case it reports the current best available estimate, together with its uncertainty

The behavior of the hybrid positioning feature is determined by the configuration of the sensors and of the setting of the accuracy and timeout parameters. For example:

- To get the best possible position fix, set the desired accuracy very small, e.g. 1 m, and the timeout period duration long. The hybrid positioning feature then runs to the end of the timeout period, and produces the final, best, output position fix
- To get a position estimate with the minimum energy consumption, for maximum battery life, set a large desired accuracy figure for the hybrid positioning, e.g. 1 km, (see the Figure 24, most likely the AS sensor position degraded or the GNSS one will be quickly returned if the time spent is below 30s)

☞ u-blox is extremely mindful of user privacy. When a position is sent to the CellLocate® server, u-blox is unable to track the SIM used or identify the specific device.

☞ See the u-blox AT Commands Manual [1] for the syntax description of AT+ULOC, AT+ULOCCELL, AT+ULOCGNSS, AT+ULOCIND and AT+ULOCAID commands.

☞ The detailed response provides useful information about the sensor used to estimate the position. When the sensor reported is "0" this means that the device has been able to calculate the position to sufficient accuracy immediately by means of the integrated AS Sensor, and has output this immediate position estimate.

6.3 GNSS sensor setup

The AT+ULOCGNSS command sets up the GNSS sensor for hybrid positioning. It is possible to configure which aiding types and GNSS systems (refer to section 4) are available to the GNSS sensor. The additional parameters, listed below, are available for modifying the GNSS receiver behavior. These are strictly related to the GNSS receiver. The parameters are sent at GNSS power on and are not saved within the receiver. The default values are the same as those on the positioning chip/module. For values and additional details about their effect refer to the u-blox Receiver Description document related to the u-blox GNSS receiver [10] [11] [12] [13]:

- UBX-CFG-PM2 message configures the power save mode of the GNSS by setting the optimization target flag in power consumption or in default mode
- UBX-CFG-NAVX5 message configures the minimum number of satellites for navigation, minimum satellite signal level for navigation and if the initial fix must be 3D
- UBX-CFG-NAV5 configures the static hold mode: allows the navigation algorithms to decrease the noise in the position output when the velocity is below a pre-defined "Static Hold Threshold". This reduces the position wander caused by environmental issues such as multi-path and improves position accuracy especially in stationary applications. By default, static hold mode is disabled
- UBX-CFG-SBAS enable/disable: SBAS (Satellite Based Augmentation Systems) is an augmentation technology for GNSS, which calculates GNSS integrity and correction data with RIMS (Ranging and Integrity Monitoring Stations) on the ground and uses geostationary satellites (GEOs) to broadcast GNSS integrity and correction data to GNSS users. The correction data is transmitted on the GNSS L1 frequency (1575.42 MHz), and therefore no additional receiver is required to make use of the correction and integrity data
- UBX-CFG-ITFM configures Jamming/Interference monitor: enables/disables the indicator, sets the antenna type, broadband jamming detection threshold and continuous wave jamming detection threshold
- UBX-CFG-GNSS configures the GNSS system channel sharing configuration and activation for a multi-GNSS receiver. For details about valid configurations see the u-blox Receiver Description document related to the u-blox GNSS receiver [10] [11] [12] [13]

6.4 Cellular sensor setup

6.4.1 AT+ULOCCELL

AT+ULOCCELL command pre-configures the device to determine which cell information must be reported to the CellLocate® server for the position estimation as follows:

- "normal scan": the cellular module only reports the parameters of the neighboring visible cells designated by the network operator, which are normally collected by the module during its "network" activity. This configuration is suitable for a quick, rough update of location
- "full scan": the cellular module scans and reports all visible cells. This gives not only the parameters of the visible cells of the serving network operator, but also the cells of all other available network operators, thus improving location accuracy. Although this takes a bit longer time (approx 30 s to 2 minutes is needed to perform a full scan), and requires more communication traffic, as more data is sent to the server (9 bytes for each cell), the coverage, reliability and accuracy are all substantially better if hybrid positioning is pre-configured to operate in the "full scan" mode of operation

☞ Full scan configuration is strongly recommended to achieve the best performance for Hybrid positioning and CellLocate®.

☞ 3G modules always operate in "full scan" mode, unless they are forced to work in 2G-only RAT.

6.4.2 AT+ULOCAID

AT+ULOCAID command lets the user application provide to the CellLocate® service information that may be useful for:

- The computation of the best solution: knowing the dynamics of the device (direction, speed…) may help in changing the weights given to different solution candidates
- The robustness of the solution provided: some of the solution candidate may be un-compatible with the possible position evolution of the device

The user has the possibility to specify its state (position and velocity) at a given time. This information will be sent to the server only with the next +ULOC command.

☞ Using +ULOCAID command will increase the total amount of data sent with +ULOC command by 24 bytes.

The module state may be retrieved from:

- Independent sensors: user application must specify epoch, position and speed vector.
- Previous CellLocate® multi-hypotheses: user application must specify the index of the hypothesis known to be the correct one

6.4.3 AT+ULOCIND

AT+ULOCIND command enables URCs sending in the case of +ULOC operations. The URC returns the result of the steps of an +ULOC operation.

6.5 AT command examples

Command	Response	Description
AT+UGSRV="cell-live1.services.u-blox.com","cell-live2.services.u-blox.com","abcdefg890abcdefg890ab",14,4,1,65,0,15	OK	MGA access configuration. A valid authentication token must be supplied to correctly access the MGA server. GNSS sensor is configured with GPS+GLONASS system for AssistNow Offline aiding (65)
AT+UPSDA=0,3	OK	Activate the GPRS connection previously configured
AT+ULOCCELL=1	OK	Configure for full network scan.
AT+ULOCGNSS=15,,4	OK	Enable all GNSS aiding modes and set the minimum number of satellites for navigation to 4
AT+ULOCIND=1	OK	Enables the localization information request status.
AT+ULOC=2,3,1,120,1	OK	Start hybrid positioning enabling both GNSS and cellular sensor with a timeout of 2 minutes and a desired accuracy of 1 m. The answer mode is detailed.
	+UULOCIND: 0,0	Network scan started
	+UULOCIND: 1,0	Network scan finished
	+UULOCIND: 4,0	A valid GNSS position was available, so this position + cells footprint is sent to the server.
	+UULOC: 08/07/2015,12:47:41.000,45.7139302,13.7405056,265,5,0,0,5,1,8,2,11	Output when the desired accuracy is reached or timeout is expired (as in this case).
AT+ULOC=2,3,1,120,100	OK	Start hybrid positioning enabling both GNSS and cellular sensor. The answer mode is detailed.
	+UULOCIND: 0,0	
	+UULOC: 08/07/2015,12:49:12.000,45.7137454,13.7404879,246,36,0,0,29,1,5,2,5	Accuracy is reached (uncertainty is 36 m) before the end of network scan, therefore the CellLocate® server is not queried.
	+UULOCIND: 1,0	Network scan finished
	+UULOCIND: 4,0	A valid GNSS position was available, so this position + cells footprint is sent to server.
AT+ULOC=2,3,2,120,5,3	OK	Start hybrid positioning enabling both GNSS and cellular sensor. Multiple hypotheses (max =3) have been requested.
	+UULOCIND: 0,0	Network scan started.
	+UULOC: 1,1,1,08/07/2015,12:55:35.000,45.7138312,13.7406267,255,4,0,49,26,6,2,22	Accuracy is reached (uncertainty is 4 m) before the end of network scan, therefore the CellLocate® server is not queried.
	+UULOCIND: 1,0	A valid GNSS position was available, so this position + cells footprint is sent to server.
	+UULOCIND: 4,0	Sending position + cells footprint to server.
AT+ULOC=2,3,2,120,5,3	OK	Start hybrid positioning enabling both GNSS and cellular sensor. Multiple hypotheses (max =3) have been requested.
	+UULOCIND: 0,0	Network scan started
	+UULOCIND: 1,0	Network scan finished
	+UULOCIND: 2,0	Requesting CellLocate® service (accuracy was not reached when network scan ended, so the server is queried)
	+UULOCIND: 3,0	Receiving CellLocate® data
	+UULOC: 1,2,1,08/07/2015,12:57:23.000,45.7139213,13.7404772,267,5,0,183,11,7,2,5 +UULOC: 2,2,2,08/07/2015,12:56:28.000,45.7138702,13.7404616,0,45.7138702,13.7404616,12,12,0,50,45.7138702,13.7404616,48,48,0,95	GNSS solution and up to N CellLocate® solutions are provided, If available.
	+UULOCIND: 4,0	Sending position + cells footprint to server

Command	Response	Description
AT+ULOCAID=1	OK	Select between one of the multi-hypotheses of a previous position request.
AT+ULOC=2,3,2,120,5,3	OK	Start hybrid positioning enabling both GNSS and cellular sensor. Multiple hypotheses (max =3) have been requested. The position estimation(s) returned by server will take count of the previous choice made by user/application (+ULOCAID=1),
	+UULOCIND: 0,0	Network scan started
	+UULOCIND: 1,0	Network scan finished
	+UULOCIND: 2,0	Requesting CellLocate® service
	+UULOCIND: 3,0	Receiving CellLocate® data
	+UULOC: 1,2,1,08/07/2015,13:03:23.000,45.7138304,13.7406099,266,5,0,0,9,7,2,5 +UULOC: 2,2,2,08/07/2015,13:02:31.000,45.7138702,13.7404616,0,45.7138702,13.7404616,16,16,0,50,45.7138702,13.7404616,68,68,0,95	
	+UULOCIND: 4,0	Sending position + cells footprint to server
AT+ULOCAID=0,"08/07/2015","13:03:32.000","45.23456","11.12345",1300,789,34,34,121	OK	Specify the state (position and velocity) of the device at a given time.

6.6 How to implement a data collection unit

The CellLocate® performance is influenced by the number of positions and related network cells reported to the server. If an area is well mapped then the position reported by the cellular sensor is more precise.

To fill the server database with the cell information of a given area, a cellular module can be used to continuously perform the hybrid positioning requests. An example of an AT sequence to implement a data collection unit is described below and it is divided into the initialization phase (section 6.6.1) and the main loop (section 6.6.2).

6.6.1 Initialization

Command	Response	Description
AT+UGSRV="cell-live1.services.u-blox.com","cell-live2.services.u-blox.com","abcdefg890abcdefg890ab",14,4,1,65,0,15	OK	Optional step only needed if the default server has been modified.
AT+ULOCCELL=1,1,"Track_ID"	OK	Full network scan configuration: the track id is optional and it is only needed to verify that the module is contributing to the server. "Track_ID" is an example.
AT+COPS=2 AT+URAT=1,2 AT+COPS=0	OK OK OK	Optional step only for 3G module to scan both 2G and 3G network: it is only needed if the default RAT has been changed.
AT+UPSD=0,1,"YOUR_APN"	OK	Data connection configuration to communicate with the server. "YOUR APN" is an example.
AT+UPSDA=0,3	OK	Activate the data connection.

6.6.2 Loop

This is the main loop to feed the server database; repeat the sequence (the suggested interval between two subsequent iterations varies depending on the dynamic conditions: 2 minutes for static or low-dynamic, 1 minute for highway speed).

Command	Response	Description
AT+UPSND=0,8	+UPSND: 0,8,X OK	If the data connection is down (X="0") start it using the command AT+UPSDA=0,3.
AT+ULOC=2,3,1,120,100	OK	Start hybrid positioning enabling both GNSS and cellular sensor.
	+UULOC: 23/05/2011,12:23:48.000,45.714115,13.740867,292,333,0,000,19,1,7,3,5	When a result is available wait before starting a new iteration, in this way the calculated position and the harvested cells are sent to the server.

7 GNSS impact on module current consumption

If the AT+UPSV command enables the power saving configuration on the cellular module (refer to u-blox AT commands manual [1] or u-blox CDMA AT Commands Manual [20] for more details), the communication between the cellular module and the GNSS receiver requires the cellular module to exit the low power idle-mode (minimum power consumption) and enter active-mode to be able to read data on the DDC (I^2C) interface: this means an increment in power consumption. This extra power consumption is negligible if the power saving configuration of the cellular module is disabled.

☞ If the cellular module transmits the GNSS information over the air by (e.g. data connection), the data transmission significantly increases the cellular module power consumption.

To evaluate the current consumption for the cellular module (not including the GNSS receiver), the GNSS update rate has been set to 1 s and the GNSS task has been configured for no data output (e.g. writing on the FS); two different GNSS message configurations have been used:

1. Standard configuration
2. Only UBX-NAV-SOL and UBX-NAV-SVINFO messages

It is possible to perform a rough estimate of the cellular module power consumption due to the DDC (I^2C) communication based on the amount of data sent by the GNSS receiver:

- The DDC interface is configured to 100 kHz, this means that the cellular module will read about 60 bytes during each GSM frame.
- The cellular module reads the GNSS registry by the DDC interface every 200 ms (~40 GSM frames): this is the default polling mode (with the "GNSS data ready" function not enabled) for the cellular module that reads the data from the DDC interface even if the GNSS receiver has no data to communicate.

Using the default DDC polling mode with the two different GNSS message configurations and the GNSS update rate defined above, the cellular module current consumption will be affected as following:

1. ~476 bytes are sent by the GNSS receiver and read by the cellular module every 200 ms, so that 8 GSM frames are needed for data transfer every ~40 GSM frames: in this case, the cellular module will be kept out of the low power idle-mode for an extra 20% (8 / 40)
2. ~264 bytes are sent by the GNSS receiver and read by the cellular module every 200 ms, so that 5 GSM frames are needed for data transfer every ~40 GSM frames: in this case, the cellular module will be kept out of the low power idle-mode for an extra 12.5% (5 / 40)

The "GNSS data ready" function improves the cellular module's power consumption because it avoids polling the DDC (I^2C) bus when no GNSS data is available: if the AT+UGPRF command enables this function (refer to u-blox AT commands manual [1] for more details), the cellular module will be kept out of the low power idle-mode only when the GNSS data is updated.

Using the "GNSS data ready" function with the two different GNSS message configurations and the GNSS update rate defined above, the cellular module current consumption will be affected as following:

1. ~476 bytes are sent by the GNSS receiver and read by the cellular module every 1 s, so that 8 GSM frames are needed for data transfer every ~200 (~40 x 5) GSM frames: in this case, the cellular module will be kept out of the low power idle-mode for an extra 4% (20% / 5)
2. ~264 bytes are sent by the GNSS receiver and read by the cellular module every 1 s, so that 5 GSM frames are needed for data transfer every ~200 (~40 x 5) GSM frames: in this case, the cellular module will be kept out of the low power idle-mode for an extra 2.5% (12.5% / 5)

Appendix

A Compatibility matrix

A.1 “GNSS data ready” compatibility matrix

GNSS	Status
Antaris	Not supported
Antaris 4	Not supported
u-blox 5	Not supported
u-blox 6	Supported from FW 7 and later firmware versions
u-blox 7	Supported, but needs to be configured via +UGUBX
u-blox M8	Supported, but needs to be configured via +UGUBX

Table 28: “GNSS data ready” compatibility matrix

As an example, the command to configure the “GNSS data ready” on UART1 TX pin is:

```
AT+UGUBX="B5 62 06 00 28 00 01 00 00 00 D0 08 00 00 00 E1 00 00 00 00 00 00 00 00 00 00 00 00 19 00
84 00 00 00 00 00 00 00 07 00 07 00 02 00 00 00 95 C3"
```

Where the meaning is:

Bytes	Meaning
B5 62	UBX message header
06 00	CFG-PRT message
28 00	Message length (40 bytes)
01	Port UART 1
00	Reserved
00 00	txReady
D0 08 00 00	UART mode
00 E1 00 00	Baudrate
00 00	In protocols (none)
00 00	Out protocols (none)
00 00	Flags
00 00	Reserved
00	Port I2C
00	Reserved
19 00	txReady (enable pin 6)
84 00 00 00	DCC Mode
00 00 00 00	Reserved
07 00	In protocols
07 00	Out protocols
02 00	Flags
00 00	Reserved
95 C3	Checksum

Table 29: +UGUBX parameter meaning

A.2 “GNSS RTC sharing” compatibility matrix

☞ Not supported by LISA-C2 series modules.

GNSS	Status
Antaris	Not supported
Antaris 4	Not supported
u-blox 5	Not supported
u-blox 6	Supported from FW 7 and later firmware versions
u-blox 7	Supported
u-blox M8	Supported

Table 30: “GNSS RTC sharing” compatibility matrix

A.3 AssistNow Autonomous compatibility matrix

GNSS	Status
Antaris	Not supported
Antaris 4	Not supported
u-blox 5	Not supported
u-blox 6	Supported from FW 7 and later firmware versions
u-blox 7	Supported
u-blox M8	Partially supported (refer to u-blox Receiver Description [13] for any limitation)

Table 31: “AssistNow Autonomous” compatibility matrix

B Cellular module and GNSS receiver compatibility matrix

Table 32 summarizes compatibility between cellular modules and GNSS receivers.

Cellular module	Positioning chips and modules	Positioning chips and modules Flash version
LEON-G100 / LEON-G200 series	u-blox 5	5.00
		6.02
	u-blox 6	6.02
		7.01
		7.03
	u-blox 7	1.00
LISA-U1 series	u-blox 6	6.02
		7.01
		7.03
	u-blox 7	1.00
LISA-U2 series	u-blox 6	6.02
		7.01
		7.03
	u-blox 7[1]	1.00
LISA-C2 series	u-blox 6	6.02
		7.01
		7.03
	u-blox 7	1.00
SARA-G340 / SARA-G350 series[2]	u-blox 6	6.02
		7.01
		7.03
	u-blox 7	1.00
	u-blox M8	2.00
SARA-U2 series	u-blox 6	6.02
		7.01
		7.03
	u-blox 7	1.00
	u-blox M8	2.00

Table 32: Cellular module and GNSS receiver compatibility matrix

[1] u-blox7 is supported by “02” product versions, and by configuring the "GNSS data ready" via +UGUBX command.
[2] u-blox M8 is not supported by SARA-G340-00S, SARA-G350-00S and SARA-G350-00X product versions.

C Compatibility and migration matrix between external application, cellular product and GNSS receiver

The following notation has been applied:

Notation	Definition
New FW	SARA-U2, SARA-G340-01S, SARA-G350-01S, SARA-G350-01B, LISA-U200-03S, LISA-U201-03S
Old FW	All products not belonging to New FW
New App	The external application suited for New FW
Old App	The external application suited for Old FW
Old server	Old aiding server
MGA	Multi-GNSS Assistance server

Table 33 highlights what has to be done or not from the point of view of an external application.

Application	Cellular	GNSS	Server	Remarks
Old App	Old FW	u-blox 6, u-blox 7	Old server	Ok
Old App	Old FW or New FW	u-blox M8	None	It cannot use MGA server and aiding mode, and the features coming with new AT command: i.e. +UGPS=1 will power on the GNSS module with the default configuration in the GNSS module. Refer to GNSS documentation to compatibility. **Deprecated**
Old App	New FW	u-blox 6, u-blox 7	Old server	OK but MGA server cannot be used
New App	New FW	u-blox 6, u-blox 7	Old server or MGA	It can use the new MGA server (use of old server is deprecated)
New App	New FW	u-blox M8	MGA	It can take advantage of all new features

Table 33: Compatibility/migration table

D Summary of interface changes and new features (u-blox M8)

Features	Changes
GNSS Power Management +UGPS	Added a third optional parameter
A-GNSS unsolicited indication +UUGIND	Added new error indications
GNSS profile configuration	No changes
AssistNow Online configuration +UGAOP	Used only for legacy
AssistNow Offline configuration +UGAOF	Used only for legacy
GNSS aiding request command +UGAOS	No changes
Sending of UBX string +UGUBX	No changes
+UGZDA +UGGGA +UGGLL +UGGSV +UGRMC +UGVTG +UGGSA	Output extended to more GNSS systems (Talker ID)
Ask for localization information +ULOC	No changes
Configure GNSS sensor +ULOCGNSS	Parameter used to configure GNSS system
Configure cellular location sensor (CellLocate®) +ULOCCELL	No changes
Aiding server configuration +UGSRV	Additional command to configure MGA server and other parameters It uses HTTP and not UDP
Authentication Token	Needed to access the MGA Server
AssistNow Autonomous	Automatically enables local aiding

Table 34: u-blox M8 interface changes and new features

E Best practices for CellLocate® (+ULOC)

The following is a list of the best practices for using hybrid positioning:

- It is suggested the use the detailed response, to know the sensor used in the position returned:
  - last valid position degraded in time (assuming as speed ~100 km/h)
  - the GNSS fix
  - the CellLocate® location information
- Once the +ULOC AT command is sent, the user/application should wait for the corresponding URC +UULOC before issuing the command again. In any case the command can be aborted, but in this way the position returned is the available position at that time (which may not be the best one).
- The use of the CellLocate® sensor and/or some aiding mode requires a data connection, which must be active until the URC +UULOC is received.
- The network scan type can either be "normal" or "deep". This influences the amount of data exchanged with the server. (On 3G modules only the deep scan is used, unless they are not set in GSM-only RAT).
- The network scan type can either be "normal" or "deep". This also influences the time needed to complete the scan, so the timeout value should be set accordingly. Be aware that the cell information is sent to the server only when the scan is completed, so setting a small value for the timeout means that the scan information will not be used:
  - "normal" is similar to sending AT+CGED=0, so it lasts about 1 or 2 s
  - "deep" is similar to sending AT+COPS=5. The duration is related to the number of visible cells; it could last about 1 minute (average value)
- The behavior of the hybrid positioning feature is determined by the configuration of the sensors and of the setting of the accuracy and timeout parameters:
  - to get the best possible position fix, set the desired accuracy very small, e.g. 1 m, and the timeout period duration long
  - to get a position estimate with the minimum energy consumption, for maximum battery life, set a large desired accuracy figure, e.g. 1 km

F Best practices for a data collection unit

The following is a list of the best practices for implementing a data collection unit:

- Set the type of network scan to "deep".
- Set the RAT type to use all technologies (this step does not apply to 2G modules).
- Set the minimum number of satellites for navigation, <minSV>, in +ULOCGNSS to 4.
- If an aiding mode is needed, use AssistNow Offline (in +ULOCGNSS set <aiding> to 2), to limit the data exchange between the module and the server, because the network scan is very sensitive to the data traffic.
- Start the hybrid positioning by enabling both GNSS and CellLocate® sensors. The suggested values are:
    - <timeout> = 120 s for low dynamic or 60 s for high speed (highway)
    - <accuracy> = 100 m

  With these values, the suggested command is: AT+ULOC=2,3,1,120,100
- The CellLocate® performance depends on how much the database is populated: submitting new fixes will improve the CellLocate® overall performance.
- Positions submitted to the u-blox database are anonymous, so it is impossible to retrieve the real identity of a device.
- If the CellLocate® service must be tested, a "tag" is suggested to ease the debugging from the u-blox side:
    - AT+ULOCCELL=1,1,"Tag_ID"

G CellLocate® customer proxy server

The proxy server implementation for the devices using HTTP is very straightforward. The customer's proxy server must listen on port 80 (for HTTP) and once a request is received, just forward it on to the u-blox CellLocate® HTTP service without token acknowledgement.

☞ The products using the HTTP interface are the ones implementing the command +UGSRV (see the u-blox AT Commands Manual [1]).

The port 80 (the default port for all HTTP connections) must be opened if not already opened.

The HTTP is a connection-oriented request-response protocol, whereas the UDP is connectionless. This means once the client has sent a request to the server, the connection remains open to the server and the client can receive the response from it. Hence, every request is managed against the device without any problem, unlike UDP where the user needs to ensure the requests are going to the correct device, etc.

☞ See the CellLocate® customer proxy server application note (WLS-SW-11001) that describes the UDP proxy implementation for products not supporting HTTP. u-blox reccomends using the HTTP interface for all the products that support it.

As with most other Internet traffic, the requests to the u-blox services are standard HTTP requests. If the requests originate from within a private network, then configure a standard HTTP proxy or firewall to forward requests and pass back responses between the private network and the u-blox services on the public Internet. No special handling is needed, as the requests are all standard HTTP requests. The users should communicate to their local IT/network administrators to correctly enable this access.

If the services are accessed via an HTTP proxy or firewall, all the requests may appear to come from the HTTP proxy or firewall itself. To avoid overuse restrictions being applied in this case, follow these steps:

- Inform u-blox of the IP address of the HTTP proxy or firewall so that overuse restrictions can be removed for this IP address.
- Configure the HTTP proxy or firewall to append the actual source IP address of the request to the standard HTTP "X-Forwarded-For" header field

If these conditions are met, then overuse restrictions will be correctly applied to the source device rather than the HTTP proxy or firewall itself. The users should communicate to their local IT/network administrators to ensure this is the case.

H List of Acronyms

Abbreviation / Term	Explanation / Definition
3GPP	3rd Generation Partnership Project
AT	AT Command Interpreter Software Subsystem, or attention
CI	Cell Identity
DDC	Display Data Channel
DLC	Data Link Connection
FS	File System
FW	Firmware
GLONASS	Globalnaya navigatsionnaya sputnikovaya sistema
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HTTP	HyperText Transfer Protocol
I2C	Inter-Integrated Circuit
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Station Identity
LAC	Location Area Code
LES	Location Estimation Service
MCC	Mobile Country Code
MGA	Multi-GNSS Assistance
MNC	Mobile Network Code
NMEA	National Marine Electronics Association
QZSS	Quasi-Zenith Satellite System
SV	Satellite Vehicle
TA	Timing Advance
TTFF	Time To First Fix
UART	Universal Asynchronous Receiver-Transmitter
UBX	u-blox
UDP	User Datagram Protocol
URC	Unsolicited Result Code

Related documents

[1] u-blox AT Commands Manual, Docu No UBX-13002752

[2] u-blox Multiplexer Implementation in cellular modules Application Note, Docu No UBX-13001887

[3] 3GPP TS 27.010 – Terminal Equipment to User Equipment (TE-UE) multiplexer protocol (Release 1999)

[4] u-blox LEON-G100 / LEON-G200 series System Integration Manual, Docu No UBX-13002023

[5] u-blox LISA-U series System Integration Manual, Docu No UBX-13001118

[6] u-blox LEON-G100 / LEON-G200 series Data Sheet, Docu No GSM.G1-HW-09001

[7] u-blox LEON-G100 / LEON-G200 series Data Sheet for LEON-06, Docu No UBX-13001913

[8] u-blox LISA-U1 series Data Sheet, Docu No UBX-13002048

[9] I^2C-bus specification and user manual - Rev. 5 - 9 October 2012 - NXP Semiconductors, http://www.nxp.com/documents/user_manual/UM10204.pdf

[10] u-blox 5 Receiver Description, Protocol Specification, Docu. No GPS.G5-X-07036

[11] u-blox 6 Receiver Description, Protocol Specification, Docu No GPS.G6-SW-10018

[12] u-blox 7 Receiver Description, Protocol Specification, Docu. No GPS.G7-SW-12001

[13] u-blox M8 Receiver Description, Protocol Specification, Docu. No. UBX-13003221

[14] AssistNow Services Quick Start Guide, Docu. No UBX-14003139

[15] u-blox LISA-U2 series Data Sheet, Docu No UBX-13001734

[16] u-blox LISA-C200 Data Sheet, Docu No UBX-13000623

[17] u-blox SARA-G3 series Data Sheet, Docu No UBX-13000993

[18] u-blox SARA-G3 / SARA-U2 series System Integration Manual, Docu No UBX-13000995

[19] u-blox LISA-C200 and FW75-C200/D200 CDMA System Integration Manual, Docu No UBX-13000620

[20] u-blox LISA-C200 and FW75-C200 AT Commands Manual, Docu No UBX-13000621

[21] u-blox SARA-U2 series Data Sheet, Docu No UBX-13005287

☞ For regular updates to u-blox documentation and to receive product change notifications, register on our homepage.

Revision history

Revision	Date	Name	Status / Comments
-	20-Jan-2010	mice	Initial release
P1	26-Jan-2010	mice	Inserted Table 1 - AssistNow data request format and Table 2 - AssistNow data confirm format. Added 4.3.2.1; Modified 5.3 Replaced BB chip with LEON
2	11-Feb. 11, 2010	mice	Removed 2.1 - Details on GPS connections in the EVA-KIT Removed Table 1 - AssistNow data request format and Table 2 - AssistNow data confirm format.
3	08-Mar- 2010		Abstract updated Chapter 4.2: WAS: In case no information of the previous position is available, a central position of the network should be BECOME: In case no information of the previous position is available, a central position of the network is used
4	01-Jul-2010	mice/ lpah	Updated the subtitle to: GPS Implementation and Aiding Features in u-blox cellular modules Added the reference to 3.5G HSDPA AT Commands Manual Chapter 1.1: added the applicability of the document to the products Added 3.4; Modified 3: added some details about handling with different firmware Added GPS start diagrams Added note on multiple +UUGIND in 4.2; Modified 4.3.1: case of multiple almanac plus file Add description about +UUGIND in 4.3.2; Modified Figure 18
4	25-Aug-2010	fves	Chapter 4.2: Updated maximum cell coverage radius (WAS: 30 km, BECOME: 35 km)7
A	09-Jun. 09, 2011	lpah	LISA-U1/LISA-H1 series and LEON-G100-06x/LEON-G200-06x supported Added description for AssistNowAutonomous, GPS Tx Data Ready, GPS RTC sharing, CellLocate and Hybrid Positioning
A1	02-Aug-2011	lpah	Removed LISA-H1 series
A2	16-Jan-2012	mcel / lpah	Extended to include functionalities description LISA-U1 series GPS Data Ready, GPS RTC sharing and AssistNow Autonomous supported by LISA-U1 series (except for LISA-U1x0-00 versions) Corrected the example where the "OK" was missing and aligned the example structure to AT examples commands application note
A3	21-Aug-2012	mcel / lpah	Extended to LISA-U2 series modules
A4	12-Apr-2013	wcos/ lpah	Extended to SARA-G350 series modules. Removed LISA-U1x0-00S versions (Last revision with old doc number, GSM.G1-CS-09007)
R12	20-Sep-2013	mcel / lpah / jpau	Updated GPS data ready applicability on u-blox 7 Added note on GPS tunneling on SARA-G350 modules Extended to LISA-C200 series modules
R13	28-Jul-2014	sfal / wcos / lpah	Document applicability extended to SARA-G340 and SARA-U2 cellular modules Rearranged section 2 Updated recommended I^2C voltage translator and clarified I^2C circuits remarks Added jamming and EMC considerations Document applicability extended to Positioning support for multi-GNSS receiver
R14	17-Jul-2014	mace	Added hybrid positioning best practices
R15	14-Sep-2015	mace	Added CellLocate® customer proxy server, section G

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